PHD

Using evolutionary theory to support lifestyle change and improve health in people at risk of developing chronic diseases

Grey, Elisabeth

Award date:
2018

Awarding institution:
University of Bath

Using evolutionary theory to support lifestyle change and improve health in people at risk of developing chronic diseases.

Elisabeth Beatrice Grey

A thesis submitted for the degree of Doctor of Philosophy

University of Bath
Department for Health

October 2018

Table of contents

List of Tables

List of Figures

Abbreviations

BCT	Behaviour change technique
BMI	Body mass index
BMR	Basal metabolic rate
CHO	Carbohydrate
CRP	C-reactive protein
CVD	Cardiovascular disease
EI	Energy intake
ELISA	Enzyme-linked immunosorbent assay
FFQ	Food frequency questionnaire
HDL	High density lipoprotein
HOMA-IR	Homeostasis model assessment for insulin resistance
LDL	Low density lipoprotein
IMD	Index of multiple deprivation
MET	Metabolic equivalent
MVPA	Moderate and vigorous physical activity
NHS	National Health Service
NI	Northern Ireland
NICE	National Institute for Health and Care Excellence. Please note that before April 2005 this institute was known as the National Institute for Clinical Excellence and, between April 2005 and March 2013, as the National Institute for Health and Clinical Excellence. The titles used in the reference section are those used at the time of publication.
PA	Physical activity
PAL	Physical activity level
RCT	Randomised controlled trial
SDT	Self-determination theory
T2DM	Type 2 diabetes mellitus
TEE	Total energy expenditure
TPB	Theory of planned behaviour
UK	United Kingdom
US	United States

Acknowledgements

Firstly, I would like to thank my supervisors, Dylan Thompson and Fiona Gillison. I feel incredibly lucky to have had two such kind, wise, positive and supportive people guiding me through this project. Their commitment to high quality health research and improving people's lives has been truly inspiring. They have also been generous enough to involve me in their other projects, which have been great experiences and helped broaden my thinking on this PhD.

I also wish to thank Jonathan Milner, who funded this project and my studentship – without Jonathan's amazing generosity, this work would not have been possible and I will forever be grateful for the opportunities he has provided.

My thanks also go to my participants – again, this research could not have taken place without them. Particularly in the last study, the interaction with my participants really kept me motivated.

I am very grateful to my PhD student colleagues for their friendship, advice and support – this would have been a very lonely undertaking without them, not to mention much less fun. Particular thanks for lab assistance/crash courses in 'how to be a physiologist' go to Oly, Iain and Stanley. And for lifting my spirits and sharing in problems, great thanks go to Rhiannon, Harriet, Siobhan, Becky and Dana. Thanks also go to my family and friends outside 'PhD world' for the walks, runs, gardens and helping me keep things in perspective.

Publications

Grey, E.B., Gillison, F.B. and Thompson, D. (2018). Can the evolutionary mismatch concept help to generate interest in health promotion messages? *Health Education Journal*, 1-12.

Conference proceedings

Grey, E.B., Gillison, F.B. and Thompson, D. (2018, August). *Evolife: A pilot trial of a web-based, evolutionary mismatch-framed intervention targeting physical activity and diet*. Poster presented at the European Health Psychology Society's annual conference in Galway.

Grey, E.B., Gillison, F.B. and Thompson, D. (2016, December). *Could the evolutionary mismatch concept help to generate interest in health promotion interventions?* Paper presented at the UK Society for Behavioural Medicine's AGM in Cardiff.

Grey, E.B., Gillison, F.B. and Thompson, D. (2016, April). *Evolution and health promotion: could they work together?* Poster presented at the Postgraduate Research Showcase, University of Bath.

Abstract

This research sought to develop and test a health behaviour change intervention for overweight and inactive UK adults, aged 35-74 years, using the concept of an evolutionary mismatch to frame health information. The mismatch concept posits that human culture has evolved too rapidly for biological evolution to keep up, meaning the human body is poorly adapted to cope with the modern environment, predisposing us to chronic disorders.

The first study explored whether using the mismatch concept to frame health information would be acceptable and engaging to target users. Mismatch-based text and graphic resources were shown to participants in semi-structured interviews. They had good acceptability, generated interest and seemed to provide a meaningful rationale for behaviour change. Following further development, the second study tested whether the resources could improve people's understanding of the effects of physical activity and diet on health and bring about change in theory-based cognitive determinants of behaviour. This questionnaire-based study found the resources enhanced knowledge and effected positive changes in most of the targeted cognitions. The mismatch resources were then developed into an online intervention also incorporating evidence-based behaviour change techniques. The third study evaluated this intervention in a pilot randomised controlled trial. The intervention did not lead to significantly greater improvement in physical activity or diet than a minimal intervention comparison, however the behavioural and health changes achieved in the intervention group were of meaningful effect size. Process evaluation provided partial support for hypothesised mechanisms of behaviour change. The findings suggest the mismatch concept could be a useful frame to stimulate initial interest and motivation in health interventions; combined with additional behavioural techniques this can help promote healthy lifestyle change. Further work is needed to test the efficacy of a mismatch-framed intervention among populations of different ages, ethnicities and religious beliefs.

CHAPTER 1. Introduction

1.1 Context

Advances in health care and social living conditions over the last hundred years or so have led to a rise in life expectancy of people in the United Kingdom (UK) from 54 years in 1919 to 81 years in 2018 (Frieden, 2010; Gapminder World, 2018). Premature death by infectious disease or lack of food is now relatively rare and new medical technologies and treatments are enabling people with chronic health conditions to live much longer than ever before (The King's Fund, 2013). In parallel with the advances in society, however, there has been rising prevalence of non-communicable, chronic disorders, particularly type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD), that were once uncommon or even unknown (Lieberman, 2013). The high and increasing prevalence of these chronic conditions is placing a huge strain on the UK economy; the direct and indirect costs to the UK of T2DM alone were £8.8 billion and £13.1 billion, respectively, in 2011 (Hex, Bartlett, Wright, Taylor & Varley, 2012). Approximately 10% of the NHS budget is spent on T2DM care and, unfortunately, this cost is forecast to rise such that, by 2035, 17% of the NHS budget will be accounted for by T2DM spending (Hex et al., 2012). Costs for cardiovascular disorders in the UK, are similarly high and set to rise (Cebr, 2014). Acknowledging these costs and following prevalence modelling research conducted by Public Health England (2015b), the Chief Knowledge Officer for Public Health England, John Newton, commented that tackling these chronic diseases "is fundamental to the sustainable future of the NHS" (Public Health England, 2015a). Furthermore, on an individual level, living with these chronic disorders can be limiting and frustrating, which takes its toll on the emotional wellbeing of the individual and their families (Diabetes UK, 2014).

Non-communicable chronic disorders, such as T2DM and CVD, are not simply inevitable consequences of the fact that people are living longer – they are not caused by normal aging processes (Hayflick, 1998). Instead they are largely attributable to factors traditionally associated with the lifestyle of people in high income countries, such as more sedentary, office-based jobs and diets composed of highly processed, energy rich but low fibre foods (Botchwey, Falkenstein, Levin, Fisher & Trowbridge, 2015; Mokdad, Marks, Stroup & Gerberding, 2004). This has led to them being termed 'diseases of affluence' and 'Western diseases' (Ezzati et al., 2005). Indeed, a troubling consequence of attempts to stimulate economic growth in lower and middle income countries seems to be a concomitant rise in levels of obesity (Davey, Allotey & Reidpath, 2013; Stevens et al., 2012) and associated biomarkers (Ezzati et al., 2005) that, over time, often lead to disorders such as T2DM and CVD. It is important to note, however, that among long-established developed countries, such as the UK and United States, these 'diseases of affluence' are increasingly more prevalent among those in the lowest socioeconomic groups (Ezzati et al., 2005).

Given their strong association with lifestyle factors, particularly physical activity, diet and tobacco smoking, many incidences of non-communicable chronic disorders could be prevented by lifestyle modification (Danaei et al., 2009; McGinnis & Foege, 1993; Mokdad et al., 2004). This has been documented for decades by health professionals, academics and policy makers; for example, the US Surgeon General's report on Health Promotion and Disease Prevention in 1979 recommended a variety of individual lifestyle changes related to nutrition and exercise for people of all ages. Since then many large clinical trials have shown that even modest lifestyle changes can have a significant impact on health. For example, engaging in moderate physical activity for at least 30 minutes a day and reducing body mass by 5%, can lower the risk of progressing to T2DM in an individual with impaired glucose regulation by around 50% (Greaves et al., 2011).

Many different strategies have been employed by national and local government, health organisations and charities to promote healthy behaviour change. In the UK, for example, the following approaches have been attempted: environmental interventions (e.g. creating cycle lanes to promote cycling over car use), changing legislation (e.g. making it illegal to smoke in enclosed public spaces), national awareness campaigns (e.g. 'Dry January' to encourage people to abstain from alcohol during January) and individual-level interventions (e.g. National Health Service (NHS) Health Checks that aim to detect early signs of T2DM and CVD in 40-74 year olds). These measures are in addition to a multitude of commercial services and products, such as weight-loss programmes, personal training classes and an ever-increasing market of foods claiming to have extraordinary health benefits.

However, even the combined force of all the aforementioned strategies has had limited impact and the prevalence of obesity, physical inactivity and associated disorders and hospital admissions continue to rise (Bhatnagar, Wickramasinghe, Wilkins & Townsend, 2016; Diabetes UK, 2018; NHS Digital, 2018). One problem is that only a small proportion of people who could benefit from the support available (such as Health Checks, exercise referral schemes and subsidised commercial weight-loss programmes) actually make use of it (Lorenc, Petticrew, Welch & Tugwell, 2013). For example, 70-90% of the people using weight management support services are women, despite more men than women being overweight or obese

(Robertson et al., 2014). In order to reach a wider proportion of the population, new services that appeal to different audiences are needed. A further concern with existing strategies to promote healthy lifestyles is that they show limited long-term effectiveness, i.e. healthy behaviour change might be initiated but is often not maintained after a year or more (Kwasnicka, Dombrowski, White & Sniehotta, 2016; Sniehotta, Simpson & Greaves, 2014). For example, there is an urgent need for strategies to support weight maintenance after initial weight loss, with evidence showing that the majority of people usually regain all the weight they lose within three to five years (Avenell, Broom, Brown, Poobalan & Aucott, 2004; Dombrowski, Avenell & Sniehotta, 2010). Systematic reviews and meta-analyses of the long-term effectiveness of interventions aimed at increasing physical activity have also shown that a majority of individuals become less active or inactive when intervention support and techniques end (Amireault, Godin & Vézina-Im, 2012; Marcus et al., 2006; Müller-Riemenschneider, Reinhold, Nocon & Willich, 2008). Continued contact with health professionals and provision of intervention materials is costly however, and risks placing individuals in a position of dependency (Bellg, 2003); it is preferable to enable people to lead healthy lives, and to want to lead a healthy life, of their own volition.

1.2 Health knowledge

A key part of enabling people to lead healthy lives is ensuring that they are well informed about risks to health and the behaviours that promote or prevent good health (Naidoo & Wills, 2005; Nutbeam, 2000). Possessing an accurate knowledge of health empowers an individual to make informed choices about factors that affect his or her health (Naidoo & Wills, 2005; Tones & Tilford, 2001). As such, the provision of health information to educate the public (i.e. increase their knowledge) is a key task for health promotion (Nutbeam, 2000; Robertson, 2008; Tones & Tilford, 2001). Many health promotion interventions aiming to provide information to help prevent T2DM and CVD have focused on highlighting the risks of unhealthy behaviours (i.e. that they can cause disease) and giving advice about how to act in order to be healthier. In so doing, these interventions have aimed to alter the cognitions that psychologists and behavioural scientists have proposed determine behaviour (Abraham, 2012a). For example, highlighting risks could change people's beliefs regarding their susceptibility to disease, and providing people with knowledge of how to act in order to become healthier could influence their perceived behavioural control or self-efficacy (Robertson, 2008).

In line with advertising and 'social' marketing practice, most health promotion interventions aiming to increase physical activity and improve diet distil complex educational messages into simple ‘soundbites’ (such as “eat five-a-day”, for promoting consumption of fruit and vegetables), ostensibly to improve the likelihood that the messages will be understood and remembered (Piggin, 2012; Piggin & Lee, 2011). These interventions seem to have been effective in raising awareness of a link between health and behaviour: UK population surveys have found high levels of awareness of basic health messages relating to healthy eating (limiting salt intake, reducing fat intake and consuming at least five portions of fruit and vegetables per day) and physical activity (that activity is desirable for health; Roberts & Marvin, 2011).

However, in striving for simplicity, much of the health promotion information available fails to explain *why* or *how* certain behaviours are risky or beneficial. Although more detailed information is available to the public - for example, on the internet or in leaflets provided at health centres - people need to actively seek it out, meaning they first must be interested and motivated to do so (Crutzen & Ruiter, 2015; Protheroe, Estacio & Saidy-Khan, 2015). Furthermore, official public health messages and recommendations, particularly around diet but also physical activity, have often changed over time (Knox, Esliger, Biddle & Sherar, 2013; Patterson, Satia, Kristal, Neuhouser & Drewnowski, 2001), and the plethora of articles on health and fitness that appear daily in the media are often seen to be contradictory to each other and official recommendations (Wilson, 2007). Conflicting and changing messages can result in great confusion, concern and scepticism and even, in some instances, a backlash effect where health messages are deliberately defied (Gazmararian, Curran, Parker, Bernhardt & DeBuono, 2005; Goldberg, 1992; Patterson et al., 2001; Wilson, 2007).

1.3 Is there a need for a deeper understanding?

Given the rising prevalence of obesity, physical inactivity and associated disorders (NHS Digital, 2018), the current awareness of simple health messages held by the UK public does not seem to be helpful in promoting behaviour change or long-term maintenance of healthy behaviours. Indeed, it has been argued, supported with qualitative research, that the simplistic health messages portrayed in health campaigns and many media resources result in limited health knowledge and literacy, which in turn leads to confusion and making unhealthy choices (Block et al., 2011; Spiteri Cornish & Moraes, 2015). A deeper understanding of *why* certain behaviours can lead to obesity and chronic disorders might help people to see the need for behaviour change and also enable them to make better lifestyle choices without having to rely on rigid rules. Furthermore, having a deeper understanding could enable individuals to critically reflect on new health-related messages that they are confronted with; that is, with a better understanding of how their body works, they might be better placed to judge whether new information is likely to be true or is relevant to them. However, in order to help people develop a deeper understanding it is necessary to convey information that is, of course, more detailed than the simple soundbites commonly portrayed. The challenge is to provide the information so that it is interesting and easy to comprehend while still sufficiently detailed.

1.4 An evolutionary mismatch concept could be used to provide a deeper understanding

A concept that might prove useful in providing more in-depth health information is that of an evolutionary mismatch between the human genome and the modern environment of high income countries. It has been proposed that many of the chronic disorders that are becoming so prevalent today are consequences of the changes to the cultural environment which have occurred in a relatively short period of our evolutionary history (Eaton & Konner, 1985; Konner & Eaton, 2010). This idea is known as the mismatch or discordance hypothesis (Eaton & Konner, 1985; Trevathan, 2007), which posits that:

- The human genome was shaped over hundreds of generations to be adaptive for environmental conditions that no longer exist
- Changes to the human environment (including dietary and activity changes) have occurred too rapidly for the genome to adapt
- The human body is thus poorly adapted to cope with the modern environment of high income countries and the adaptations that were once beneficial now predispose us to chronic diseases.

The concept of an evolutionary mismatch might be particularly helpful in framing health information for a number of reasons: firstly, it provides an over-arching framework for introducing information on human evolution, physiology and behaviour, thus enabling more in-depth information to be delivered in a cohesive manner; secondly, the mismatch concept can help explain not only *what* lifestyle factors cause disease (which, as highlighted, might not be the major issue preventing behaviour change in the UK) but also *why* these factors cause disease. For instance, examples can be highlighted of how the human body has been shaped by conditions where physical activity was a necessity and diets typically comprised low energy density foods, such as the adaptations for efficient fat storage or muscle's role in glucose uptake. It can then be shown how these adaptations interact with the modern environment, where technology largely removes the necessity for physical activity and highly energy dense foods are easily available, to make us susceptible to excessive body fat and disease development. In this way the mismatch concept can also be used to help explain the epidemic levels of obesity and associated chronic disorders that are commonly reported in the news.

An evolutionary frame is particularly apt for considering obesity and non-communicable disorders since it provides insight on the multiple risk factors for these conditions rather than focusing on just one. Many health promotion interventions have targeted one risk factor (e.g. sugar intake) or only risk factors within either the diet or physical activity domain, but there is growing evidence that combined interventions, employing techniques that target both diet and physical activity, are more effective for weight management (Greaves et al., 2011; Johns, Hartmann-Boyce, Jebb & Aveyard, 2014). Furthermore, several studies have highlighted that interventions employing simultaneous delivery of techniques are more effective than interventions that sequentially deliver techniques, targeting different risk factors in turn (Hyman, Pavlik, Taylor, Goodrick & Moye, 2007; King et al., 2013; Vandelanotte, 2013). It is well known that health risk behaviours, such as poor diet and low activity levels, tend to occur in clusters (Spring, Moller & Coons, 2012), therefore targeting them in one intervention also makes good economic sense (Vandelanotte, 2013).

The evolutionary mismatch concept might also be useful for delivering health-related information since it would be novel: most health promotion messages do not discuss evolution. Novelty of format or content is known to be an important factor in gaining people's attention and interest in health-related information, particularly when people are confronted with many different messages (Crutzen & Ruiter, 2015; Louis & Sutton, 1991). Using an evolutionary mismatch frame therefore might also help engage audiences who would not normally be attracted to health information. On the other hand, it is important that new information is believable and relevant in order to be accepted (Cappella, 2006). The fact that many cultural changes, leading to a reduction in physical activity and change in diet, have occurred in the last 50 years might help to enhance the believability and relevance of the mismatch message since adults will be able to reflect on the changes that they have lived through (e.g. increasing car use).

Finally, drawing on the evolutionary mismatch concept might also help to provide a useful model or simple tool for making healthy lifestyle choices. For example, when confronted with an array of foods to choose from it could be helpful to consider which is likely to be closest to the foods available to our ancestors (i.e. foods containing the least refined sugar, fat and salt, all of which are known to heighten the risk of chronic disease; Katz, 2005). However, care would need to be taken that such a model is not too restrictive or perceived as being dogmatic. The Paleo diet, for example, was originally based on the mismatch concept but advocates trying to consume only foods that would have been eaten by Palaeolithic hunter-gatherers, eschewing all foods that came only after humans began farming, about 12,000 years ago (Cordain, 2002). While the Paleo diet has proved popular, its exclusion of multiple food groups, such as dairy and cereals, has been criticised as too restrictive for long-term adherence (U.S. News and World Report, 2015; Zuk, 2013). Others have highlighted that focusing on one period of human history neglects the evolutionary adaptations that have shaped us prior to and after this period and suggest that taking a broader view of human evolution can give a more accurate understanding of what we are and are not adapted for (Lieberman, 2013; Zuk, 2013).

1.5 Overview of thesis

The research presented in this thesis is the development and piloting of a health behaviour change intervention for overweight and inactive people using the concept of an evolutionary mismatch to help them understand not only *what* lifestyle factors cause disease (which, as highlighted, might not be the major issue preventing behaviour change in the UK) but also *why* these factors cause disease. The core frame of the intervention will be that of the evolutionary mismatch (i.e. that changes to our environment have happened too quickly for bodies to adapt). The familiar messages of the need to be physically active and consume a healthy diet will be addressed from the mismatch perspective: highlighting how rapidly the change to these factors has occurred, in what ways our bodies are adapted to ancestral diets and physical activity levels and a basic overview of the physiological effects of modern lifestyles in high income coutries. Importantly, the positive aspects of cultural evolution will also be highlighted in order to show that a return to ancestral lifestyles, which would likely be immediately off-putting, is not being advocated. Rather, the emphasis will be on making small, sustainable changes in the areas where rapid cultural evolution is causing harm (i.e. physical activity and diet).

In line with current guidance on developing health interventions (Craig et al., 2008), this research draws on theory and evidence to help design and evaluate the intervention. The fields of behavioural science and health communication have advanced rapidly in recent decades, identifying many potential ways to influence people's cognitions and, ultimately, their behaviour. The studies presented in this thesis first explore people's perceptions of using the evolutionary mismatch concept as a frame for delivering health information, then test the ability of a set of mismatch-framed information resources to influence cognitions that are thought to determine behaviour. Finally, a randomised controlled trial aims to test the ability of a mismatch-framed, internet-based intervention to promote increased physical activity and healthy dietary change. The findings from these studies will be drawn together and the implications for practice and future research will be discussed.

CHAPTER 2. Literature review

2.1 Evolution and health

2.1.1 Fundamental points of evolution

Evolution is the process through which organisms change over succeeding generations. The main mechanism of evolution is natural selection, which can be defined as "the process whereby organisms better adapted to their environment tend to survive and produce more offspring" (Oxford Dictionaries, 2015b). Natural selection is dependent on three phenomena: variation, genetic heritability and differential reproductive success (Lieberman, 2013). Variation refers to the differences between individual organisms within a species – these can be differences in physical traits, such as leg length or eye colour, or behavioural traits. Traits differ in the extent to which they are genetically heritable, that is, the extent to which they are determined by genes and thus can be passed on to the next generation by parents passing their genes to their offspring. Variation in genetically heritable traits occurs due to random mutations in genes. Differential reproductive success refers to the fact that individual organisms differ in the number of offspring they produce, who in turn are able to reproduce. Due to differences in reproductive success, heritable traits will become more or less frequent in succeeding generations. Traits that increase an individual's ability to produce more offspring than fellow members of their species (their 'relative fitness') are said to be adaptive. Natural selection occurs since adaptive traits are, by their nature, more likely to increase in frequency in the subsequent generation, causing change in populations over generations (i.e. evolution). Traits that detract from an organism's ability to reproduce tend to decrease in frequency in the next generation.

It is important to note that adaptations (adaptive traits) enhance an individual's ability to have more surviving and viable offspring, which is not necessarily going to promote health or longevity. However, a certain degree of health is obviously required to reproduce and the ability to survive to reproductive age will also be necessary. Furthermore, adaptations are context dependent. A trait might be adaptive in a certain environment but not in others; an example is fair skin, which is adaptive for people living in temperate climates where there are low levels of ultraviolet light as it allows more vitamin D to be synthesised by the skin. However, fair skin provides poor protection against sunburn and so is not adaptive for environments where light levels are intense and regular. Since our environment is constantly changing – both due to natural forces and man-made changes – the adaptive value of traits changes. Thus, it is incorrect to think of any organism as perfectly or optimally adapted for a certain environment. As Lieberman explains, "natural selection constantly pushes organisms to optimality, but optimality is almost always impossible to achieve" (2013, p.12). Instead we have a multitude of traits that are adaptive for different environments. An additional complication in the concept of adaptation is that adaptive traits have costs as well as benefits. The large human brain might allow complex and rapid thought but it also requires a lot of energy and increased head size, making childbirth more dangerous (Smithsonian Institution, 2015a).

2.1.2 Human evolution

Humans belong to the Primate order; chimpanzees are our closest relatives and our lineages are estimated to have diverged from a common ancestor about 6-8 million years ago (Smithsonian Institution, 2014d). This coincided with the start of increasing climate variability and an overall cooling of the earth's climate (Potts, 2003). The resultant environmental instability is hypothesised to have driven the evolution of two key anatomical features that distinguish humans from chimpanzees: upright bipedalism and larger brains relative to body size (Potts, 2003). While the subsequent species in the chimpanzee lineage remained physiologically adapted for a mostly tree-dwelling lifestyle, subsequent species in the human lineage became better adapted for walking upright on two legs, having more side-ways facing pelvises, S-shaped spines, arched feet and hyper-extensive toe joints (Bramble & Lieberman, 2004). Bipedalism is thought to have enabled early Hominins to move around more easily in a diverse range of habitats, thus allowing them to leave the African rainforest in which their primate ancestors dwelt (Leonard, 2010; Potts, 2003). During this time, the early Hominin species (Ardipethicines and Australopithecines) led scavenger lifestyles, subsisting primarily on plant foods, like their primate ancestors, but also eating meat from carcasses left by predators (Eaton & Konner, 1985; Garn & Leonard, 1989). Meat contains no dietary fibre and so can be digested faster; thus with the introduction of meat to the Hominin diet the need for the long primate gut reduced and in more recent Hominin species shorter digestive tracts are found (Leonard, 2010). The absence of fibre in meat also makes it a more concentrated source of energy, protein, fat and micronutrients compared to plants; for this reason the introduction of meat is also thought to have been instrumental in enabling an increase in Hominin brain size (Carmody, Weintraub & Wrangham, 2011; Leonard, 2010).

Brain size increased modestly such that when the first species in the Homo genus (Homo habilis) emerged 2.6 million years ago, its average brain size was about a third of modern man's (Lieberman, 2013). A period of major climate fluctuation, between 800,000 and 200,000 years ago, coincided with a rapid increase in brain size among subsequent Homo species (Smithsonian Institution, 2014a). Larger, more complex brains enable more processing and storage of information and higher cognitive capacities, such as planning ahead and reasoning (Smithsonian Institution, 2015a). These are qualities that would have better enabled our ancestors to navigate and solve the increasingly diverse environmental challenges they faced as the climate changed. However, brain tissue requires high amounts of energy, roughly 16 times more energy than an equivalent mass of muscle tissue (Leonard, 2010). Thus with the increase in brain size came an increasing need for a high quality diet, in terms of both energy and nutrients (Leonard, 2010).

Alongside our biological evolution it is also important to consider cultural evolution. Culture, in this context, can be defined as 'the ideas, customs and social behaviour' of a species (Oxford Dictionaries, 2015a). Just as Hominin anatomy gradually changed over millions of years, so Hominin culture made modest advances since the divergence from the apes 6 million or so years ago up until the first Homo sapiens. Cultural innovation can be seen in the tools our ancestors used. The first crude hand axes were knapped from stone about 2.6 million years ago and allowed Homo habilis to hunt and kill prey, rather than depend on scavenging, and thus meat consumption could increase (Garn & Leonard, 1989). Hand axes remained the tool of choice apparently for two million years, gradually becoming larger and more sophisticated in shape to cope with a greater range of tasks (Smithsonian Institution, 2014e). By 500,000 years ago long spears were also made, which would have enabled hunting of large game animals.

The control of fire around 800,000 years ago represents a major milestone in Hominin cultural evolution; the campfire provided a means of cooking food, protection from predators, a source of warmth and a place for early humans to socialise and share information (Smithsonian Institution, 2014b). The ability to cook is believed to have been crucial to human evolution as cooked foods take less time to eat and are easier to digest, thus allowing more calories to be consumed in a shorter time and at less expense (Carmody et al., 2011; Carmody & Wrangham, 2009; Fonseca-Azevedo & Herculano-Houzel, 2012; Ragir, 2000). This further prompted the evolution of a shorter digestive tract (Carmody & Wrangham, 2009; Ragir, 2000).

These cultural advances kept pace with, indeed were driven by, Hominin biological evolution, but the emergence of complex-brained Homo sapiens has seen cultural evolution rapidly advance and outstrip biological evolution. Archaic Homo sapiens (anatomically modern man) first emerged around 200,000 years ago, with the largest brains of all the Homo species (Lieberman, 2013). At first, the pace of innovation in tool making rose, allowing a greater variety of food to be hunted or gathered, including fish and shellfish (Smithsonian Institution, 2014e; Winston, 2002). These provided a rich source docosahexaenoic acid, an essential fatty acid that is rare in other foods but is thought to have played an important role in further increases in Homo brain size (Crawford et al., 1999).

Methods of communication became more sophisticated and social networks more complex. By 130,000 years ago different social groups, located hundreds of miles apart, would interact and exchange resources (Smithsonian Institution, 2015b). Further cultural advances include symbolic art, making clothing and ceremonial and burial practices, which emerged between 100,000 and 50,000 years ago. The complexity of early Homo sapiens' brains enabled, and were in turn shaped by, the increasing communication, cooperation, innovation and problem solving of their cultural evolution (Winston, 2002). By 40,000-50,000 years ago, the combination of these capabilities in Homo sapiens is seen as defining them as behaviourally modern, that is, capable of similar behaviours to man today (Klein, 1995).

Most of Hominin history took place in Africa, although, as previously mentioned, climate changes meant that our ancestors experienced a diverse range of conditions, depending on the period in which they lived, and they also occupied different regions within Africa. Although other Homo species left Africa and started to spread out across Europe and Asia about one million years ago (National History Museum, 2015a), Homo sapiens evolved from species that remained in Africa and it was not until about 60,000 years ago that sapiens started to migrate across Eurasia (National History Museum, 2015b). Different groups of sapiens travelled to and settled in different regions; the novel environmental conditions each group faced placed differing selective pressures on them, leading to the evolution of regional differences in appearance and physiology. The most obvious example of such differences is skin colour (as previously mentioned) but others include less body hair combined with more working sweat glands in people living in hotter climates (Smithsonian Institution, 2014c)

The novel environmental challenges faced by our ancestors after they left Africa also seem to have spurred on cultural evolution (Winston, 2002). New tools were invented for catching, gathering and processing the different animals and plants encountered. For example grinding stones, thought to have been used to make pastes or flour from cereal grains, have been found in separate areas of Europe and date back to 30,000 years ago (Revedin et al., 2010). Basket weaving and pottery making occurred 26,000 years ago in China and would have enabled storage of foods as well as a new means of holding water in cooking (Smithsonian Institution, 2014e). Homo sapiens' apparently unique ability to innovate and use culture to adapt to different environments enabled them to thrive in diverse locations, grow in population size and ultimately outcompete other Homo species (Lieberman, 2013; Winston, 2002).

One of the most profound cultural transformations began about 12,000 years ago: the agricultural revolution. Up until then, Hominins had scavenged, hunted and gathered wild animals and plants, but about 12,800 years ago a few societies living around the Eastern Mediterranean started experimenting with cultivating plants (Lieberman, 2013). Within a thousand years figs, barley, wheat, chickpeas and lentils were successfully farmed. Although farming practices spread from here gradually throughout the Middle East, Europe and Africa, it is likely that they were invented separately and slightly later (about 10,000 years ago) in Asia and America (Lieberman, 2013). With agriculture came an increasing proportion of grains in the diet (Cordain et al., 2005). Since grains are particularly amenable to being stored (more so than fruit and vegetables) they presented a food source that could help sustain people from one harvest to the next (Garn & Leonard, 1989). However, this led farmers to focus their effort and crop space on a few staple cereal crops, sacrificing quality and variety for quantity, which in turn led to vitamin and mineral deficiencies in their diet (Kuipers, Joordens & Muskiet, 2012). The skeletal remains of early cereal farming communities show a diminution in body size and bone thickness compared to the late Palaeolithic hunter-gatherers, testament to their nutrient deficient diets (Garn & Leonard, 1989).

At first, agriculture was likely supplemented by hunting, providing a small amount of meat (Lieberman, 2013). Animals such as goats, boar, sheep and cows were later domesticated in various parts of the world (beginning around 10,600 years ago in the Middle East) and this provided a more reliable, and much needed, source of animal protein. Dairy farming is thought to have originated in Northern Europe about 9,000 years ago and the harsh winter climates in this region placed a strong selective pressure for lactase persistence into adulthood among these populations (Ingram, Mulcare, Itan, Thomas & Swallow, 2009). Lactase is required to digest lactose in milk products but in most animals, lactase production stops after infancy (Ingram et al., 2009). Dairy products provided a valuable source of energy when little plant material could grow in the Northern winters and so individuals with the genes for lactase production into adulthood were at an evolutionary advantage. Lactase persistence is an example of genetic evolution that has occurred since the agricultural revolution but it is also a reminder of the limited pace at which such evolution takes place in humans; only 35% of the world's population are lactase persistent (Ingram et al., 2009).

Farming also represents an important milestone in human evolution because it enabled rapid population increase. Hunter-gatherers, on average, would have only enough food to sustain a mother and one dependent child, whereas farmers tended to have enough food for a mother and several dependent children at once (Lieberman, 2013). Thus parents were able to wean their children at one to two years as opposed to three to four years as was typical for hunter-gatherers (Lieberman, 2013). Since nursing acts to reduce fertility, especially when combined with a low energy intake, the longer nursing times of hunter-gatherers effectively acted as prolonged contraception (Lieberman, 2013). Farming also had a significant impact on the physical environment, which affected those people who remained as hunter-gatherers as well as the farmers. The most fertile and accessible land is, understandably, taken for crops but this depletes the land and natural resources available for wild animals and hunter-gatherers. The few remaining hunter-gatherer societies around today are forced to live in marginal environments, with few natural resources, and many now trade with farming communities for food (Konner & Eaton, 2010).

Farming techniques gradually progressed over the centuries as new tools were invented and careful selection (by man) of crops and livestock developed more reliable and high yielding food sources. Since farmers were tied to their land, and with the population increase, larger settlements became established, creating the first towns and cities. While these facilitated trading of goods and social co-operation, living in large groups in close proximity to animals also aided the spread of infectious disease, with sometimes disastrous effects on populations (Lieberman, 2013). Maritime transport developed alongside farming and enabled the import and export of different foods between countries. However, sea travel was dangerous which limited the reliability and amount of international food trade that could occur. The sixteenth century saw the introduction of several new food sources to Britain from the Americas, including sugar and potatoes, however, most imported goods remained the preserve of the rich for many centuries (Lambert, 2014).

A further major change in human history occurred relatively recently, thousands of years after the agricultural revolution. The industrial revolution began about 250 years ago and saw the harnessing of fossil fuels to power machines that could produce and transport goods in huge quantities (Lieberman, 2013). The first machines were designed to produce textiles, a job formerly done by individuals alongside other jobs, such as tending the land. Within a few decades, though, new machines were invented that took over many other tasks which had previously relied on manual labour or domesticated animals, such as ploughing, transport, milling. People relocated from rural areas to be closer to factories and so large cities developed around these works. This spurred the development of government institutions to organise, care for and regulate the changing society. Capitalism took off, creating further industries to finance, advertise and sell goods. With mechanised transport, international travel became safer and more reliable, enabling more trade in crops and making imported foods less expensive (Lambert, 2014). Within a few generations the lives of people in industrialised societies changed profoundly: workers specialised in one or a few tasks, long distance travel became more accessible, family structure and social hierarchies were reconfigured.

Machines also started to take over food processing. A particularly significant invention was the mechanical grain roller, which replaced the stone wheels that people had manually operated for thousands of years to mill grains to make flour (Pollan, 2008). The rollers not only took away the need for physical effort in flour production but also enabled the complete refinement of cereal grains; stone grinding could remove the bran from grains (and thus the fibre) but the rollers could also remove the 'germ' or embryo, which contains oils that are rich in nutrients. As well as making much whiter flour, removing the germ leaves a more stable product that can be stored for longer and hence transported further. White flour soon became one of the staple ingredients in the diet of high income countries (Pollan, 2008).

Our cultural evolution seems to be continuing at an ever-increasing pace. Although some regions of the world are only just beginning to industrialise, among the original adopters of industrialisation, technology and innovation have continued to advance at an exponential rate. The industrial revolution sparked an interest in science, the driver of industrial innovation (Lieberman, 2013). Advancement in biological and medical science brought about many benefits to public health, such as sterilising techniques and vaccines. These have helped humans overcome some of the infectious disease that were consequences of the agricultural revolution and early industrialisation (Lieberman, 2013). Developments in chemistry and engineering throughout the twentieth century have made machines, such as cars, that were formerly only available to the rich, attainable commodities for the majority. Food science emerged as a lucrative industry in the twentieth century, introducing artificially synthesised foods, such as high fructose corn syrup. Since these foods could be easily and cheaply manufactured they quickly took the place of naturally grown or reared resources in the diets of many in the developed world; indeed throughout the 1960s, 1970s and 1980s, as large supermarkets increasingly became the main places to buy food and their focus was on providing products as cheaply as possible, it became harder to obtain unprocessed foods than processed (Pollan, 2008).

2.1.3 Dietary adaptations

The previous section showed how we have evolved from plant-eating primates, with diets very high in fibre, through periods of scavenging and hunter-gathering, when meat and, later, cooking brought a higher quality of diet (i.e. a diet where more of the energy contained in the foods consumed can be extracted and used by the body; Power & Schulkin, 2009). Then farming brought a temporary return to a lower quality, plant-based diet, characterised by an over-dependence on a single cereal or starchy vegetable (Kuipers et al., 2012; Lieberman, 2013), before animal domestication provided protein from meat and dairy. Most recently the dawn of mechanised processing and food science have made highly energy dense, low fibre foods plentiful and cheap. Although our ancestors have survived, and even thrived, on a variety of diets depending on when and where they lived, several factors have been relatively constant up until the mid-twentieth century: fibre intake was high and foods that were rich in simple sugars and fats were rare or difficult to obtain (Garn & Leonard, 1989; Power & Schulkin, 2009). Thus for most of human history, diets were of much lower quality, in terms of energy density, than they are today and so traits that helped our ancestors maintain sufficient energy and essential nutrients to survive were selected.

2.1.3.1 Efficient energy storage: 'thrifty' genotypes and phenotypes

One example of an evolved adaptation is humans' ability to store excess energy from our diets as fat. Humans as a species have relatively higher proportions of body fat than other primates: adult primates have about 6% body fat; adult hunter-gatherer (i.e. lean) males have about 10% body fat, females 20% (Lieberman, 2013); the Encyclopaedia Britannica now lists 16% as a healthy body fat percentage for a lean adult male and 22% for lean adult females (Weininger, 2015). Tracing human ancestry reveals that our increasing fat reserves coincided with increasing brain size, which is logical since our larger brains require a constant, plentiful supply of energy which our fat reserves help to maintain (Lieberman, 2013; Winston, 2002). Women need even higher amounts of fat as they also have to produce food for their large-brained offspring, both in utero and while breast-feeding. Indeed, women's reproductive systems are extremely sensitive to changes in energy balance; negative energy balance (i.e. more energy expended than taken in) for a normal weight woman decreases chances of conception (Lieberman, 2013).

A couple of explanations have been put forward for how this propensity to store fat evolved and why population differences in fat storage occur. Over 50 years ago Neel (1962) proposed the thrifty genotype hypothesis as a possible explanation for why certain people are more susceptible to type 2 diabetes mellitus (T2DM) than others. The hypothesis reasons that natural selection during humans' time as hunter-gatherers would have favoured genes that enabled greater fat storage, since these would better enable both survival and reproduction through periods of food scarcity. Neel further proposed that societies that had been farming for longer would have fewer of these thrifty fat storage genes in their gene pools because farmers would have a more reliable and plentiful food supply and so these genes would hold less of an advantage for them (Neel, 1962). The thrifty gene hypothesis has thus been used to explain the high levels of obesity and T2DM occurring in hunter-gatherer societies that have recently adopted 'Western' lifestyles, such as Australian Aborigines and the sub-section of Pima Indians, originally from Mexico, who now live in the United States (Schulz et al., 2006). There is higher prevalence of T2DM among these people than there is among their relatives who still live as hunter-gatherers, but also, crucially, higher prevalence than other US or Australian citizens (Schulz et al., 2006).

However, several predictions that stem from the thrifty gene hypothesis have failed to be substantiated. Thrifty gene variants (i.e. variants that promote efficient storage of excess energy as fat) have indeed been isolated and identified but they do not seem to be more prevalent among populations that have recently adopted a 'Western' lifestyle (Hu, 2011; Lieberman, 2013). Also, it could be expected that populations which had more recently adopted agriculture would be more likely to have higher rates of metabolic mismatch disorders than those that had adopted agricultural practices earlier. Yet this has not consistently been found; for example, many South Asian communities have long been farming yet still have relatively high rates of metabolic syndrome, a clustering of risk factors for cardiovascular disorder (Lieberman, 2013). Furthermore, the thrifty gene hypothesis would predict that during periods of relative food abundance, hunter-gatherers would gain significant amounts of fat, which would then help sustain them through times of scarcity. Although hunter-gatherers' body mass does fluctuate seasonally, the variation is small; that is, they do not seem to stock up on fat (Speakman, 2007). A further problem with the thrifty gene hypothesis lies in its rationale that food supplies were more consistent and plentiful for farmers than hunter-gatherers. Speakman (2007; 2008) illustrates, however, that famines were actually more common, and only posed a selective force, when humans became dependent on crops and livestock for their entire diet. This is due to farming communities' over-reliance on single food sources (i.e. their crops), which meant that a crop blight could completely wipe out a population. And farming practices, such as growing many plants in close proximity and lack of crop rotation, increase the risk of blight.

The thrifty phenotype hypothesis (Hales & Barker, 1992) was put forward as an alternative to help explain the variation in prevalence of metabolic syndrome and T2DM. Importantly the thrifty phenotype hypothesis acknowledges the importance of the gene-environment interaction in the development of these disorders. The hypothesis proposes that poor foetal growth impacts on an individual's subsequent glucose metabolism, such that they are less able to process large amounts of sugar. Foetal growth is strongly affected by maternal food intake and so, from an evolutionary perspective, the thrifty phenotype hypothesis makes sense: if food is scarce a pregnant mother will be less able to sufficiently feed herself and her developing child; the foetus will develop less muscle, fewer insulin-producing pancreatic cells and smaller organs. This will make the child better able to cope with the famine conditions both in utero and later in the external world, since they will be smaller, requiring less energy. Problems arise, however, if the environment becomes one of relative abundance; in such circumstances the individual cannot produce enough insulin, due to their paucity of pancreatic cells, and will be more prone to obesity and T2DM (Hales & Barker, 1992).

The thrifty phenotype hypothesis helps to explain the association between low birthweight and adult development of metabolic syndrome and T2DM, which has been found in many populations including British (Hales & Barker, 1992), American, Pima Indians living in the US (McCance et al., 1994), and Indian and South Asian (Yajnik, 2004). Indeed, the thrifty phenotype hypothesis has been used to help explain the recent rapid rise and disproportionately high prevalence rates of T2DM in India and other Asian countries, in comparison with high income countries (Hu, 2011). Undernutrition has long been (and still is) a problem in these areas yet the diets and lifestyles typical of high income countries are rapidly being adopted, meaning it is a common scenario for many to experience poor nutrition in utero and early life followed by over-nutrition in later life (Hu, 2011). However, the thrifty phenotype hypothesis fails to account for the high rates of metabolic syndrome and T2DM found among people who had relatively high birthweights, who were born to healthy or overweight mothers in affluent societies. It is possible that among these people a different mechanism is at work, one due to an excess energy intake during infancy and childhood, a phenomenon that is now possible in developed societies. In affluent societies the prevalence of childhood overweight and obesity has been increasing to crisis levels, for example a third of children in the UK were classified as overweight or obese in 2013 (van Jaarsveld & Gulliford, 2015). This is thought to be a major risk factor for adult overweight and obesity since overweight children develop a greater number of adipose (fat) cells than healthy weight children (Spalding et al, 2008) and the additional adipose cells tend to be visceral rather than subcutaneous adipose cells (Lieberman, 2013). In adulthood, the total number of adipose cells tends to remain constant (although cells are continuously dying and being replaced), thus the number of cells developed during childhood determines the number that remain throughout adulthood (Spalding et al, 2008). Increases in fat mass during adulthood occur when adipose cells increase in size to store larger amounts of fat (Spalding et al, 2008). The heightened number of visceral adipose cells found in adults who were overweight as children places the individuals at increased risk of developing T2DM because visceral fat cells are more sensitive to hormones, meaning they are faster at storing and releasing fat (Ibrahim, 2010). The fatty acids that visceral fat cells release can quickly go to the liver (due to the cells' proximity to this organ), that is, there is little opportunity for them to be taken out of the blood by other cells. A large amount of visceral fat can therefore result in an accumulation of fat in the liver which decreases the liver's ability to control glucose secretion into the blood (Ibrahim, 2010). Overall, it is likely that several mechanisms are involved in humans' propensity to store excess energy as fat. Although there is variation in different populations' tendencies to accumulate fat, it is 'uncontroversial to state that all humans are adept at storing extra energy as fat' (Lieberman, 2013, p. 262).

2.1.3.2 Defence of energy stores

As well as an enhanced ability to store fat, humans have regulatory mechanisms to prevent the loss of fat. Unlike fat storage, however, these mechanisms are shared with most mammals and thus are likely to have originated many millions of years ago in a common ancestor of the mammalian phylum (Power & Schulkin, 2009). The concept of adipose (fat) tissue homeostasis has been used to explain the empirical data that many animals, including humans, maintain relatively constant body adiposity over prolonged periods of time (Havel, 2000; Morton, Cummings, Baskin, Barsh & Schwartz, 2006). The homeostatic model proposes that the mechanisms which regulate feeding behaviour act to maintain energy balance and thus adipose tissue homeostasis (Power & Schulkin, 2009). One of the mechanisms through which food intake and energy balance is regulated in the long term is the synthesis, in adipose tissue, and secretion into the bloodstream of a hormone called leptin. The amount of circulating leptin in the blood is directly related to the amount of adipose tissue an individual has: the more adipose, the higher the leptin levels (Havel, 2000; Schwartz, Woods, Porte, Seeley & Baskin, 2000). Circulating leptin is transported across the blood-brain barrier and detected by receptors in the hypothalamus where it acts as a negative feedback regulator of adiposity by inhibiting feelings of hunger and supporting energy expenditure (Banks, 2001; Guyenet & Schwartz, 2012). When adipose tissue is depleted (i.e. fat is 'lost'), less leptin will be made and reach the brain; the decreased leptin signalling results in heightened feelings of hunger (Guyenet & Schwartz, 2012; Havel, 2000). It has been generally accepted that leptin likely served an adaptive function as an indicator of low energy stores and thus a way of responding to food adversity (Guyenet & Schwartz, 2012; Power & Schulkin, 2009). When adipose tissue was depleted, low levels of circulating leptin could have been a means of motivating animals to prioritise feeding. In support of this theory is the finding that leptin levels fall disproportionately low during fasting, inducing compensatory behaviours to acquire food (Ahima et al., 1996; Mars, de Graaf, de Groot & Kok, 2005).

The role of leptin in food intake was discovered in the early 1990s using mice models (Havel, 2000). Researchers found that knocking out the genes responsible for leptin synthesis or modifying leptin receptors to make them defective both resulted in animals with a high propensity for obesity (Power & Schulkin, 2009). Furthermore, injecting leptin resulted in significant reductions in food intake and subsequent loss of body mass in those mice that were leptin deficient but had no effect on the mice with defective leptin receptors (Halaas et al., 1995). These early findings gave hope that leptin could provide a solution for people wanting to lose weight: leptin supplements might suppress appetite. However, most obese individuals were not, unlike the mice models, found to be leptin deficient and giving extra leptin to obese mice that were not leptin deficient and did not have defective leptin receptors was not found to decrease appetite or induce weight loss (Power & Schulkin, 2009). This presented a conundrum: surely the excess adipose tissue that defines an obese state should result in high circulating levels of leptin and thus chronically reduced appetite?

It was soon discovered that a state of leptin resistance existed in some obese individuals (Morton et al., 2006). This condition is not yet well understood but it appears to involve an impairment in the ability to transport leptin across the blood-brain barrier and/or a saturation of the transporter system at the levels of leptin found in obesity (Banks, 2001; Power & Schulkin, 2009). Leptin resistance is implicated in both the pathogenesis of obesity and its maintenance, since elevated levels of leptin are required to overcome a defect in leptin signalling (Guyenet & Schwartz, 2012). However, Power and Schulkin (2009) point out that many obese people do not have defective leptin receptors. Further, they take an evolutionary perspective and propose that the leptin signalling system is better adapted to responding to states of low rather than excess leptin because the former state was more common throughout our history whereas the latter was unlikely to have occurred very often. That is, because excess food was a rarity, obesity seldom occurred and so there has been little occasion for traits to evolve that protect against obesity.

2.1.3.3 Efficient food procurement

The fact that overweight and obesity occur seems to contradict the homeostatic model of energy balance and adiposity. There are, however, many more factors that control feeding behaviour besides leptin. Feeding is the result of a complex interaction between peripheral organs and multiple brain regions. As well as short- and long-term regulation of food intake by endogenous peptides and steroids, social, environmental, learned and circadian cues can influence perceptions of hunger and satiety, and hence food choice behaviour (Cummings & Overduin, 2007; Guyenet & Schwartz, 2012). Different animals have evolved different adaptations to guide their food choices according to their body size and composition (and hence nutrient requirements) (Power & Schulkin, 2009). Taste preferences are important examples of such adaptations; they motivate us to seek out or select certain foods over others (Power & Schulkin, 2009). A specific taste preference for salt has been found in many animals and seems to be part of a broader system to defend against sodium deficiency (Schulkin, 1991). When levels of sodium in the body are low (or following significant loss of water from the body) the kidneys stimulate the renin-angiotensin system, which acts peripherally to conserve water and sodium and also affects the brain, resulting in behaviours to acquire water and salt. One effect is enhancing the hedonic perception of salt so that salty foods are preferred and actively sought (Schulkin, 1991). When sodium levels are not depleted, humans, like other omnivores, show a particular liking for moderate salt concentrations (Breslin, 2013). Carnivorous animals obtain salt with every meal and so do not show a strong preference for salty foods. Herbivorous animals, on the other hand, exhibit a very strong preference for high salt concentrations presumably because they are at greater risk of sodium depletion – they actively seek out natural salt-licks (Breslin, 2013).

A preference for sweet-tasting foods among humans has also been well documented; this exists universally and is present from birth (Drewnowski & Almiron-Roig, 2010; Drewnowski, Mennella, Johnson & Bellisle, 2012; Keskitalo et al., 2007). Naturally sweet foods are generally safe (i.e. non-toxic) and tend to contain high amounts of sugar, an easily digestible source of energy (Keskitalo et al., 2007). Since, for most of human history, food acquisition was uncertain and/or food 'quality' was low, energy dense foods, such as those high in sugar, would have provided a survival advantage. Selective forces would thus have favoured individuals with genes coding for strong preferences of sweet foods (Keskitalo et al., 2007). In support of this theory is the knowledge that taste preferences are largely genetically determined (Keskitalo et al., 2007). However, a variety of taste receptor gene variants exist, leading to slight variations in individual preferences (Keskitalo et al., 2007). Humans also show a near universal aversion to bitter-tasting foods; this is thought to be because many bitter-tasting wild foods have toxins in that, if ingested in large quantities, will cause death (Breslin, 2013; Zuk, 2013). Human preference for fatty foods is more complex – although there is increasing evidence for a fat taste (Power & Schulkin, 2009), fat is also detected by texture, with fats giving foods a thick, smooth or creamy 'mouth feel' that is associated with pleasure (Drewnowski & Almiron-Roig, 2010). As well as our innate preferences that motivate and guide food acquisition, humans and other animals can learn to associate certain environmental cues with rewarding foods (Guyenet & Schwartz, 2012; Rolls, 2012). This occurs because the taste, texture, smell and sight of a food all influence the reward system in the brain, which reinforces behaviours that have pleasurable effects (Guyenet & Schwartz, 2012).

It is clear that feeding is a complex process. Appetite and satiety, and the behaviours they invoke, are coordinated by multiple endocrine and neural systems that operate outside our conscious control. However, it is important to note that humans also have a great capacity for executive processing, due to the well-developed frontal cortex which distinguishes the human brain from most other animal brains (Elliott, 2003). Executive functions are the complex, conscious cognitions associated with coordination, control and goal-orientation (Elliott, 2003). They can overcome or modify the brains' instinctive, unconscious cognitions (such as hunger) that are generated in older parts of the brain (Elliott, 2003). By inhibiting hunger and satiety signals that come from peripheral organs, our executive function can help us refrain from eating when hungry or eat despite not feeling hungry (Power & Schulkin, 2009). Executive function can also be used to help shape our behaviour towards long-term goals, such as weight loss or fitness, and if sufficiently strong or prolonged, can alter our underlying preferences (Guyenet, 2015). However, people vary in their levels of executive function, as shown in the different amounts of willpower people have to overcome an evolved preference for sweet or fatty foods (Guyenet, 2015). The presence of strong environmental cues to eat combined with innate preferences for certain foods, can cause the reward system of the brain to override both our executive function and the satiety signals produced by stomach distension and satiety hormones, causing us to overconsume (Guyenet, 2015; Rolls, 2012).

2.1.3.4 Dietary adaptations in the modern world

This section has highlighted some of the adaptations that have helped our ancestors to maintain enough energy and nutrients to survive in environments where food availability was variable and the majority of food was low-quality. These adaptations remain in humans today and yet our environment, at least in developed countries, has vastly changed, effectively removing most of the external and internal constraints on energy acquisition (Lieberman, 2006). In high income societies, food is reliably available from a wide array of sources: as well as shops specifically selling food, there are petrol stations, vending machines and, of course, the ubiquitous presence of restaurants and cafés. Furthermore, there is copious food and drink advertising (Lieberman, 2006). Together this means that there are ever-present visual cues, stimulating the brain's reward system and prompting us to eat (Lieberman, 2006; Rolls, 2012). In an understandable market response, food producers have endeavoured to cater to our evolved preferences for sweet, fatty and salty foods (Power & Schulkin, 2009). Plants have been artificially selected not only to produce more reliable but also sweeter crops (Warinner, 2013) and livestock is bred and reared to ensure a high proportion of fat is marbled throughout the meat, thus keeping it tender during cooking (Pollan, 2008). The producers of industrially processed foods often add sugars or oils to aid shelf-life and improve palatability (Slimani et al., 2009) but with the consequence that most highly processed foods are very energy dense. Furthermore, industrial processing often involves the removal of natural fibre, again making modern foods more energy dense. Fibre adds bulk to food and thus causes distension of the stomach, an important satiety signal; greater quantities of energy dense foods are required to stimulate distension signals (Pollan, 2008; Rolls, 2012). Not only are highly processed, energy dense foods more palatable than less processed foods they are also cheap to buy and present the lowest energy cost (monetary expense per MJ gained) to the consumer (Drewnowski & Specter, 2004).

In these conditions of easily accessible, highly palatable food, our innate preferences are maladaptive, prompting us to choose highly processed foods. Among the UK general population, between 59% (female) and 62% (male) of daily food intake (by mass) is from highly industrially processed foods, making just over 75% of total daily energy intake (Slimani et al., 2009). It is easy to see how this environment can lead to chronic overconsumption and, as shown, our bodies have adapted to exploit an excess of energy by storing it as fat. Obesity thus ensues and once-adaptive systems work to defend the increased adipose tissue, preventing fat loss. It is now widely accepted that obesity, or more precisely an excess in body fat, particularly abdominal fat, heightens our risk of developing T2DM and CVD (Frühbeck et al., 2013; Medical Research Council, 2015). Furthermore, the highly refined nature of the foods that we consume today can directly heighten our risk of T2DM. The lack of fibre and high proportions of simple sugars and starches that characterise many processed foods means that they lead to rapid spikes in blood glucose levels (Livesey, Taylor, Hulshof & Howlett, 2008). In response, the pancreas secretes large amounts of insulin to enable the glucose to be removed from the blood and return blood glucose levels to normal. If highly refined foods are consumed frequently over long periods of time, insulin levels will remain high and the body can start to become less sensitive to it; over time this resistance to insulin worsens leading to diabetes (Kahn, 2003). The chronic hyperglycaemia that occurs if T2DM is poorly managed has in turn been linked to atherosclerosis (Diabetes.co.uk, 2015; Peppa, Uribarri & Vlassara, 2003). Prolonged exposure to the excess glucose molecules can lead to glycation of amino groups in lipids and protein molecules in the blood. Eventually advanced glycation end products (AGEs) are formed and these can bind with cells in the blood vessel walls, causing stiffening of the vessels: atherosclerosis (Peppa et al., 2003).

However, while overconsumption and diets comprised almost wholly of highly processed foods do undoubtedly contribute to chronic disease, they cannot totally explain the obesity epidemic and extremely high prevalence of T2DM and CVD. Indeed, examining data from national dietary intake surveys in both the US and the UK shows that average energy intakes since the mid twentieth century have fluctuated and any increases have been too small to lead to the steady rise in average body mass index (BMI) seen in these countries (Leonard, 2010; Millward, 2013). Instead it is necessary to consider dietary changes in conjunction with changes in the amount and types of physical activity that have occurred as part of our cultural evolution.

2.1.4 Physical activity through human evolution

For most of human history there was a necessary relationship between food acquisition and energy expenditure through physical activity; that is, people had to work and move in order to get food (Booth, Chakravarthy & Spangenburg, 2002; Eaton & Eaton, 2003). When the first hominids left the African rainforest for the open savannahs, they entered habitats where the food available to them was more spread out, thus necessitating walking long distances. Apes in the rainforest walk about 2-3km per day to collect their daily food intake; in comparison, contemporary hunter-gatherers living in the African savannah walk at least 6km in a day to find and collect food (Kaplan, Hill, Lancaster & Hurtado, 2000; Lieberman, 2013). Having found suitable plants, further exertion would then have been required to extract the edible parts, for example digging up a single wild tuber can take 20 minutes using primitive tools and navigating stony ground (Lieberman, 2013). Starchy tubers, such as potatoes and yams, then need further processing before they become digestible for humans, again requiring physical effort to pound the fibrous root or build a fire for cooking. The open habitat also meant plants were more affected by the seasons, necessitating a nomadic lifestyle for the humans that ate them whereby their small social groups would have to continually move and rebuild camps to be nearer food sources (Lieberman, 2013).

As well as walking and physical labour, endurance running is also likely to have been a regular activity for early hunters (Bramble & Lieberman, 2004). There is archaeological evidence that humans were hunting large animals, such as wildebeest, before they had projectile weapons (Domínguez-Rodrigo, 2002). This would have required the first human hunters to attack their prey at close range and yet humans are poor sprinters compared to quadrupeds (Bramble & Lieberman, 2004). Persistence hunting has been proposed as the method that would have been used by early hunters to enable them to get close enough to their prey (Bramble & Lieberman, 2004). This involves a hunter or group of hunters singling out a large mammal and chasing it to exhaustion by following it at an endurance running pace. The prey can sprint much faster than the hunters and escape them at first but it cannot sprint for a long time without overheating. Thus by making the prey sprint in repeated bouts over several hours the animal will eventually overheat and collapse, allowing the hunters to come in for the kill. Bramble and Lieberman argue that endurance running might have been instrumental to human evolution and show how certain biomechanical features of the human body are uniquely beneficial for running and are unrelated to walking, including hypertrophy of the gluteus maximus for trunk stabilisation and a large sacroiliac area for greater muscle attachment of erector spinae (Bramble & Lieberman, 2004).

Hunter-gatherers would also have had considerable strength. In parallel with the evolution of more dextrous hands came a greater reliance on increasingly sophisticated stone tools (Rolian, Lieberman & Zermeno, 2011; Susman, 1998; Tocheri, Orr, Jacofsky & Marzke, 2008). Although these tools enabled our ancestors to hunt a wider variety of prey (Smithsonian Institution, 2014e) and process foods more thoroughly to extract more energy from them (Revedin et al., 2010), they required substantial upper body strength to make and use (Rolian et al., 2011). Projectile tools particularly would have necessitated great power to throw with sufficient speed to kill prey (Roach, Venkadesan, Rainbow & Lieberman, 2013).

The advent of farming enabled a reduction in search time for food but would not have lessened total energy expenditure levels (Lieberman, 2013). Subsistence farming involves long days of manual labour to prepare ground, sow, protect, harvest and process crops, and tend to livestock on a daily basis. Compiling data from various studies of contemporary societies leading either a hunter-gatherer or subsistence farming lifestyle, Leonard (2008) has calculated average physical activity level (PAL) scores for the two groups. PAL scores are a measure of the total energy expended in a day relative to the minimum required by a body to function at rest in a day (i.e. total energy expenditure (TEE)/basal metabolic rate (BMR)). The average PAL of subsistence farmers was 2.07 (male) and 1.89 (female), compared with 1.88 (male) and 1.75 (female) for hunter-gatherers (Leonard, 2008). Although these scores are derived from non-longitudinal studies, and thus do not take account of the substantial seasonal variation in activity, they do highlight that the agricultural revolution would not have led to a reduction in physical activity. According to the classifications of activity levels set by the joint Food and Agriculture Organization of the United Nations (FAO) and World Health Organisation (WHO) Expert Consultation on Human Energy Requirements, both the hunter-gatherer and subsistence farmer lifestyles would be classified as 'active' (FAO, 2001). Furthermore, although the tasks undertaken changed with the shift to farming, the agricultural lifestyle would still have required a mixture of aerobic and strength building activity (Eaton & Eaton, 2003).

As societies grew in size and complexity, and new farming techniques enabled food production to go beyond subsistence level, new jobs were created meaning that, for the first time in our evolutionary history, not everyone in society was directly involved in food procurement. However, for the majority of people in these societies, daily life still required significant levels of physical activity; travel was mostly by foot, and occupational and home-based tasks were unaided by machines (Lieberman, 2013). The industrial revolution, however, led to profound reductions in physical activity levels, although, as previously highlighted, these did not occur instantaneously. The first machines were heavy and required considerable strength to operate, besides which early factory workers had to work extremely long days, thus the first industrial jobs were about as energetically demanding as farm labour (Lieberman, 2013). As technology improved and machines became automatically controlled, manufacturing occupations became less physically arduous. The automation of machinery also lead to an increase in the number of people in office-based employment as the demand for factory labourers decreased (Lieberman, 2013). The industrial revolution did, however, set in motion the scientific and economic drive to invent and produce labour-saving devices for the public. By the mid-twentieth century these devices started to affect nearly all aspects of people's lives, including their occupations (e.g. the computer), home-life (e.g. vacuum cleaners, food processors and refrigerators), leisure time (e.g. televisions) and travel (e.g. cars, escalators). This has led to an overall decline in average PALs in industrialised societies: the PALs of typical adults with office jobs in a developed country are 1.56 for men and 1.55 for women (Lieberman, 2013). These are substantially lower than the PALs obtained for subsistence farmers and hunter-gatherers (Leonard, 2008) and are classified as sedentary lifestyles (FAO, 2001). Importantly, they are also lower than the recommended minimum PAL of 1.70, set by the FAO/WHO expert consultation as this is associated with a lower risk of obesity, T2DM and CVD (FAO, 2001). Most British adults have PALs of 1.4 to 1.6 (British Nutrition Foundation, 2015).

Ng and Popkin (2012) have used historical data from the UK, US, China, India and Brazil to better understand how increasing technology has influenced different domains of human activity since the 1960s when digital technology started to become publicly available. Estimates of average energy expenditure were calculated across four activity domains (occupation, travel, leisure and domestic work) and sedentary time using survey data on time allocation and occupational distributions and standardised metabolic equivalents of task (MET) data. MET give a measure of how much energy a person expends during a task (their working metabolic rate) relative to their BMR. In all countries studied there was a trend for decreasing active time and MET hours per week, and increasing sedentary time. Focusing on the UK data, physical activity declined by 20% from 1961 to 2005 (216 to 173 MET hours/week for adults) while time spent sedentary increased by 47% (28 to 42 hours/week). The greatest decreases were in occupational and domestic work (Occupational: 146 to 95 MET hours/week; Domestic: 57 to 45 MET hours/week). Travel activity in the UK had increased since the 1960s (5 to 17 MET hours/week), which the authors attributed to the state promotion of active transport and efforts to design urban areas to be conducive to walking and cycling (Ng & Popkin, 2012). However, travel and leisure activity only contributed a very small proportion of overall activity. This study is likely to have yielded conservative estimates of the decreases in energy expenditure since the MET calculations were based on standardised METs for modern tasks, i.e. using modern technology that was not available in the 1960s. Thus, the MET hours per week given for the earlier decades are likely to be lower than were the case at the time.

2.1.4.1 Effects of physical (in)activity

The human body has evolved to interact with the environment such that external stresses (experienced through physical activity) stimulated growth or strengthening of muscle (including cardiac muscle) and bone tissue (Booth, Chakravarthy & Spangenburg, 2002; Eaton & Eaton, 2003; Lieberman, 2013; Scott, 2014b; Wolfe, 2006). In turn the stronger bones and muscles were better able to cope with further external stresses. Importantly, because physical activity was an ever-present necessity throughout most of human history, there was never a selective pressure to evolve the ability to grow or strengthen bones and muscles without the presence of activity. Through building strong bones and skeletal and cardiac muscles, physical activity helps prevent osteoporosis, CVD (Booth, Chakravarthy, Gordon & Spangenburg, 2002; Lieberman, 2013) and sarcopenia (Scott, 2014b; Wolfe, 2006). With the decreasing levels of physical activity in high-income countries that have adopted the 'Western' lifestyle, these conditions have become more prevalent (Blair, 2015; Booth, Chakravarthy, Gordon, et al., 2002; Lieberman, 2013; Scott, 2014b).

Eaton and Eaton (2003) also highlight that muscle tissue plays an important role in preventing obesity and T2DM. The regular physical activity that was necessary for the hunter-gatherer and subsistence farming lifestyles of our ancestors would likely have resulted in lean physiques; studies of various modern day hunter-gatherers invariably show them to have higher proportions of skeletal muscle compared to most people living in high income societies (Eaton, Konner & Shostak, 1988). This is important since skeletal muscle tissue is highly efficient at extracting glucose from the blood in response to insulin; exposed to the same amount of insulin in the blood, muscle tissue will extract much more glucose than the same mass of adipose tissue (Eaton & Eaton, 2003). Furthermore, the condition of muscle tissue affects its efficiency at glucose extraction, with well-conditioned (i.e. regularly exercised) muscle being more efficient (Booth, Chakravarthy, Gordon, et al., 2002; Eaton & Eaton, 2003). Thus, the proportions of muscle relative to adipose tissue will determine how quickly an individual's blood glucose levels will return to the normal range after ingesting food. With much higher proportions of adipose relative to muscle tissue, blood glucose levels will remain high, stimulating more insulin to be secreted which, as previously described, can lead to T2DM (Kahn, 2003). It is worth noting that muscle proportion is important regardless of body mass; individuals with a 'healthy' BMI (between 18.5 and 24.9kg/m^{2}: World Health Organization, 2015) can have a low proportion of muscle tissue and thus be at greater risk of T2DM (Scott, 2014b; Wolfe, 2006).

Muscle also requires much more energy to maintain than adipose tissue, thus for two individuals of comparable size but one with a greater proportion of muscle and the other a greater proportion of adipose tissue, the former will have a higher BMR (Eaton & Eaton, 2003; Wolfe, 2006). This helps to prevent obesity since, with all other factors being equal, a higher BMR means that more ingested energy will be used immediately and thus not available for storage in adipose tissue. The low muscle mass resulting from sedentary lifestyles typical of high income societies is thus problematic on several levels and is particularly cause for concern in combination with the aforementioned food environment, where there is an abundance of processed foods that are high in simple sugars.

In addition to their better muscle to fat ratios, modern hunter-gatherers and subsistence farmers in comparison to individuals in high income societies, show higher proportions of skeletal mass relative to fat mass, an indication of stronger bones (Shephard & Rhode, 1996). Cordain and colleagues (1998) have also compared the aerobic fitness levels (as measured by maximal oxygen uptake) of seven hunter-gatherer and non-industrialised farming populations with average levels for modern populations in high income societies; the traditionally living populations' fitness levels were approximately 50% higher than those of age-matched people from high income societies (VO_2 max = 57.2 ml/kg/min vs. 37.2 ml/kg/min). The favourable fitness levels of non-industrialised populations are in turn associated with improved biomarkers for cardiovascular and metabolic health. For example, Oliver, Cohen and Neel (1975) found lower blood pressure levels in the Yanamamo Indians of both Brazil and Venezuela, and better insulin sensitivity has been shown among Australian Aborigines (O'Dea, Spargo & Nestel, 1982) and Kitavan tribesmen of the South Pacific (Lindeberg, Eliasson, Lindahl & Ahren, 1999). The necessarily active lifestyle of non-industrialised societies is thus strongly indicated as a contributory factor to their low levels of T2DM and CVD.

It is not only the decrease in overall physical activity levels that has accompanied industrialisation which is cause for concern, but also the increasing time spent in sedentary pursuits (i.e. conducted while sitting). It is possible for an individual to meet current recommended physical activity guidelines of 150 minutes of moderate intensity exercise per week in bouts of at least 10 minutes (Chief Medical Officer, 2011) while still spending 95% of their waking hours sitting (Hamilton, Healy, Dunstan, Zderic & Owen, 2008). Indeed, technology today enables travel, occupational and leisure time to be spent seated. This is problematic because there is now substantial evidence illustrating the adverse effects of sedentary behaviour independent of activity levels (Hamilton et al., 2008; Owen, Healy, Matthews & Dunstan, 2010; Smith, Ng & Popkin, 2014). For example, in a study of Australian adults using objective measures of activity (accelerometers), sedentary time was positively correlated with cardiovascular and metabolic risk markers, including waist circumference and 2-hour plasma glucose levels, and these associations remained even after adjustment for time spent in moderate to vigorous intensity exercise (Healy et al., 2008). Spending long periods of time in a seated position displaces time spent standing or in light intensity activity, both of which expend more energy than sitting and help to condition muscle (Hamilton et al., 2008). From an evolutionary perspective, humans are unlikely to have had the luxury of spending such large amounts of time in sedentary pursuits. Studies of contemporary hunter-gatherer societies have shown their daily activity patterns to involve mostly light to moderate intensity activity, with bouts of vigorous intensity activity on several days a week (Cordain et al., 1998). As previously highlighted, sedentary time has only really increased in the last 50 years or so (Ng & Popkin, 2012). Levine and colleagues (2011) have proposed that increasing urbanisation has played a large part in decreasing so-called non-exercise activity thermogenesis (NEAT, i.e. energy expenditure for all activity other than sleeping, eating and deliberate sports-like exercise). These researchers examined activity patterns and energy expenditure in rural- and urban-dwelling Jamaicans using accelerometer and inclinometer monitoring technology. In order to examine the impact of urbanisation *per se,* participants in the urban and rural samples were lean and matched for body mass. Participants in the rural sample spent significantly more time each day standing and walking than those in the urban sample (Levine et al., 2011). These differences were not simply due to differences in occupations: both samples included individuals in manual occupations as well as more sedentary office-based jobs and some who were unemployed. Thus the authors concluded that the built environment is associated with low levels of daily activity and NEAT.

It has further been proposed that sedentary behaviour may have a detrimental effect on gene expression, leading to the development of chronic diseases. Applying Neel's (1962) thrifty genotype hypothesis to physical activity, Booth and colleagues have purported that certain thrifty genes respond to an absence of physical activity by stimulating physiological changes that act to conserve energy (Booth, Chakravarthy, Gordon, et al., 2002; Booth, Chakravarthy & Spangenburg, 2002; Booth, Laye, Lees, Rector & Thyfault, 2008; Chakravarthy & Booth, 2004). These researchers contend that, historically, prolonged physical inactivity would only have occurred during famines since, at these times, there would be little food to gather or hunt. Thus physical inactivity serves to stimulate physiological reactions that are adaptive for famine conditions, including a decrease in insulin sensitivity in muscle tissue, which serves to reserve glucose for storage in adipose tissue thus providing an energy source to survive a famine. Thrifty responses to inactivity have been shown in both rodent and human models, where sudden prevention of activity is followed within days or weeks by significant reductions in insulin sensitivity and increased storage of fat, particularly visceral fat (Booth, Chakravarthy & Spangenburg, 2002; Booth et al., 2008; Chakravarthy & Booth, 2004). This occurs despite calorie intake being reduced to match the decrease in energy expenditure (Booth et al., 2008). The sedentary lifestyle of high income societies still appears to trigger these thrifty responses and yet the famine conditions for which they are preparing the body never come; the reduced insulin sensitivity and increased abdominal fat, in the absence of famine, only serve to promote the onset of T2DM and CVD (Booth et al., 2008).

2.1.5 The mismatch hypothesis

The mismatch (or discordance) hypothesis was first proposed by Eaton and Konner in 1985 and was based on converging findings from genetics, palaeontology, medicine and anthropology. Firstly, the human genome was found to have changed very little since the first behaviourally modern human beings (*Homo sapiens sapiens*) emerged 40,000 – 50,000 years ago in the late Palaeolithic period (Cavalli-Sforza, 1981; Rendel, 1970). Although some genetic evolution has occurred since – demonstrated, for example, in changes to skin and eye pigmentation, adaptive defences to new microorganisms and the retention of intestinal lactase beyond infancy – the core metabolic and physiological processes have remained (Eaton, Konner & Cordain, 2010). This means that the environmental conditions that have exerted most selective pressure on our genome were those that existed prior to 40,000 years ago. Secondly, studies by various anthropologists of the few remaining hunter-gatherer societies, which are deemed to be the closest approximation to our Palaeolithic ancestors, found very low prevalence rates of the so-called diseases of affluence (e.g. Arthaud, 1970; Moodie, 1973; Truswell & Hansen, 1976). A further influential work for the mismatch hypothesis was a study in which ten full-blood Australian Aborigines, who had converted to a lifestyle typical of high income societies and had T2DM, agreed to re-adopt the traditional hunter-gatherer lifestyle for a seven week period; this resulted in significantly improved glucose and lipid metabolism, the latter being completely normalised (O'Dea, 1984). Thirdly, medical science in the 1980s was increasingly identifying factors associated with the diet and lifestyle of high income societies, adopted in the last 100 or so years, as contributing to the onset of T2DM, CVD and some types of cancer (Eaton & Konner, 1985).

Eaton and Konner's original paper proposing the mismatch concept focused on nutritional differences between the modern diet and ancestral diets; the thrust of their argument being that the human body might be better adapted to cope with ancestral diets and so ancestral nutritional intakes could provide 'a reference standard for modern human nutrition and a model for defense [*sic*] against certain "diseases of civilization"' (Eaton & Konner, 1985, p.288). Since the publication of this landmark paper, many more academics, medical professionals, anthropologists and palaeontologists have highlighted other mismatches between ancestral and modern lifestyles that have negative consequences for our health; including, for example, mismatches in activity levels (Booth, Chakravarthy & Spangenburg, 2002), exposure to natural environments (Logan, Katzman & Balanza-Martinez, 2015) and sleeping behaviour (Gettler & McKenna, 2011). Indeed the study of mismatch diseases is now a large and growing field within the discipline of evolutionary medicine, which is broadly defined as 'the application of principles of evolutionary theory to the practice and research of medicine' (Trevathan, 2007). It has further been proposed that viewing diseases such as T2DM and CVD as evolutionary mismatches could help in the effort to prevent them by identifying their environmental causes and the reasons why the body is vulnerable to them (Lieberman, 2013). The medical field has traditionally focused on the proximate causes and mechanisms of disease (Nesse & Stearns, 2008) and with good reason – a patient presenting with a heart attack requires immediate care and for their practitioners to know what is happening in their body and how to treat it or minimise the harm. However, many of the most burdensome chronic diseases in high income societies today are almost entirely preventable (Danaei et al., 2009; McGinnis & Foege, 1993; Mokdad et al., 2004); this has led to greater interest in preventive medicine and health promotion, and it is here that an evolutionary perspective is posited to prove useful. Researchers have proposed following an evolutionary-based research agenda in health promotion in order to attain an integrative, consistent foundation on which to base public health recommendations (Eaton, Strassman, et al., 2002). By investigating the differences between our ancestors' lifestyles and the modern lifestyle and, through clinical experiments, identifying which of these differences help initiate or maintain chronic disease, we should be able to make reliable and cohesive health advice and interventions (Eaton, Strassman, et al., 2002). A large number of researchers and health professionals, from various disciplines and in different countries, have been working to develop the field and, in 2009, the Ancestral Health Society was formed to foster interdisciplinary collaboration on the study of mismatch diseases and the development of solutions using an evolutionary perspective (The Ancestral Health Society, 2014).

2.1.6 Applying the mismatch concept

2.1.6.1 The Palaeolithic diet model

The Palaeolithic diet model that Eaton and Konner proposed was compiled mainly from anthropological studies, by various independent researchers, of contemporary hunter-gatherer societies (Eaton & Konner, 1985). In 2010 Konner and Eaton reviewed how well their original characterisation of the Palaeolithic diet fared in light of further anthropological findings in the intervening 25 years; they acknowledged evidence that intake of fish and shellfish played an important role in the evolution of the human brain and felt that they had underestimated this. However, they concluded that their estimations had otherwise withstood the test of time (Konner & Eaton, 2010). Although some people have questioned the usefulness of a model focusing only on the Palaeolithic period (Turner & Thompson, 2013; also see section 2.1.6.3 on The Paleo movement), the model has largely gone unchallenged as an estimation of the average Palaeolithic diet and independent researchers in the fields of anthropology and evolutionary biology have endorsed the model (Garn & Leonard, 1989; Luca, Perry & Di Rienzo, 2010).

The Palaeolithic diet proposed by Konner and Eaton (2010) includes lean meat, fish, shellfish, vegetables, fruits, eggs, nuts and small amounts of cereal grains, legumes and honey but excludes dairy products, added salt, and refined fats and sugar, which became staple foods only after the agricultural revolution. The key differences in nutrient and energy composition between the Palaeolithic-type diet and the average 'Western' diet of high income societies are shown in Table 2.1. In terms of macronutrient proportions of the Palaeolithic diet, Konner and Eaton (2010) estimate 35-40% of total daily energy intake to come from carbohydrate, 25-30% from protein and 20-35% from fat. The fat proportion is the same as is currently recommended by the UK government (35%) but the carbohydrate proportion is lower than the recommended 50% (British Nutrition Foundation, 2015). It should also be noted that the main sources of carbohydrate in the Palaeolithic diet (fruits, vegetables and nuts) differ from the typical 'Western' diet (cereal grains) and this contributes to the former containing a much higher amount of fibre. The Palaeolithic diet also contains a higher proportion of protein than is currently recommended, however, these recommendations have been called into question due to the insensitive tools used to determine protein requirements (World Health Organization, 2007). Recent research using more accurate methods has suggested that the current recommendations have underestimated protein requirements and that a moderately higher protein intake (25-35g protein at each meal) is likely to provide health benefits, including healthy ageing and successful weight management (Arentson-Lantz, Clairmont, Paddon-Jones, Tremblay & Elango, 2015).

Table 2.1 Widely agreed-on qualitative differences between average ancestral (hunter-gatherer) diets and contemporary 'western' diets

	Ancestral (Hunter-Gatherer)	Contemporary 'Western'
Total energy intake	More	Less
Caloric density	Very low	High
Dietary bulk	More	Less
Total carbohydrate intake	Less	More
Added sugars/refined carbohydrates	Very little	Much more
Glycaemic load	Relatively low	High
Fruits and vegetables	Twice as much	Half as much
Antioxidant capacity	Higher	Lower
Fibre	More	Less
Soluble:insoluble	Roughly 1:1	<1 insoluble
Protein intake	More	Less
Total fat intake	Roughly equal	Roughly equal
Serum cholesterol-raising fat	Less	More
Total polyunsaturated fat	More	Less
ω-6:ω-3	Roughly equal	Far more ω-6
Long-chain essential fatty acids	More	Less
Cholesterol intake	Equal or more	Equal or less
Micronutrient intake	More	Less
Sodium:potassium	<1	>1
Acid base impact	Alkaline or acidic	Acidic
Milk products	Mother's milk only	High, lifelong
Cereal grains	Minimal	Substantial
Free water intake	More	Less

Source: Konner and Eaton, 2010

2.1.6.2 Trials of the Palaeolithic-type diet

Eaton and Konner (1985) were careful to point out that experimental, clinical studies would be needed to test their hypotheses about the medical benefits of ancestral diets and since then a small number of trials have taken place to do so. These trials have used a more conservative diet than Konner and Eaton's model, in terms of completely omitting legumes, cereals and all dairy, which more contemporary takes on the original model advocate (see section 1.6.3 The

Paleo movement for further explanation). Otherwise the diet used in all the trials accorded with Konner and Eaton's recommendations and was based on lean meat and fish, fruit and vegetables, eggs, nuts and seeds and excluding refined sugars and fats and added salt. A summary of the results of the following trials is shown in Table 2.2.

Table 2.2 Summary of results from Palaeolithic-type diet trials

	Author (year)	Participants (N)	Design	Duration	Blood pressure	Lipid profile	Glucose and insulin profile	Body mass, WC, BMI
Comparison of Palaeolithic-type diet with normal diet	Osterdahl et al. (2008)	Healthy, normal body mass (14)	Within-subjects	3 weeks	SBP ↓	NC	NC	Body mass ↓ WC ↓ BMI ↓
	Frasetto et al. (2009)	Healthy, non-obese (9)	Within-subjects	7 days 'ramp up' + 10 days	DBP ↓ AP↓	TC ↓ LDL ↓ TG ↓	Glucose AUC – NC Insulin AUC ↓ Insulin sensitivity ↑	NR
	Ryberg et al. (2013)	Obese, post-menopausal women (10)	Within-subjects	5 weeks	DBP ↓	LDL ↓ HDL ↓ TG ↓ Liver lipid ↓	Fasting glucose ↓ Liver insulin sensitivity↑	Body mass ↓ WC ↓ BMI ↓
Comparison of Palaeolithic-type diet with healthy reference diets*	Lindeberg et al. (2007)	People with T2DM and CHD or raised blood glucose (29)	Between-subjects, RCT	12 weeks	NSD	NSD	Glucose AUC ↓	WC ↓
	Jonsson et al. (2009)	People with T2DM (13)	Within-subjects cross-over, RCT	12 weeks + 12 weeks	DBP ↓	TG ↓ HDL ↑	HbA1c ↓	Body mass ↓ WC ↓ BMI ↓
	Boers et al. (2014)	People with ≥2 symptoms of metabolic syndrome (34)	Between-subjects, RCT	2 weeks	DBP ↓	TG ↓ HDL ↑	NSD	Body mass ↓ WC ↓ BMI ↓
	Pastore et al. (2015)	People with hypercholesterolaemia (20)	Within-subjects 2-phase intervention	16 weeks + 16 weeks	NR	TC ↓ LDL ↓ TG ↓ HDL ↑	NR	Body mass ↓
Comparison of Palaeolithic-type diet with and without supervised exercise	Otten et al. (2017)	People with T2DM (29)	Within- and between-subjects, RCT	12 weeks	Both groups: SBP ↓ DBP ↓	Both groups: TG ↓ TC ↓ Exercise group: HDL ↑	Both groups: Insulin sensitivity ↑ Fasting glucose ↓	Both groups: Body mass ↓ WC ↓

NC – no change; NR – not reported; NSD – no significant difference (between diet groups); SBP – systolic blood pressure; DBP – diastolic blood pressure; AP – arterial pressure; TC - total cholesterol; TG – triglyerides; WC - waist circumference *For these trials, results are reported only for outcomes where there were significant differences between the two diets tested

Three trials of a Palaeolithic-type diet have been conducted with healthy participants, all using a within-subjects design comparing the Palaeolithic-type diet with participants' normal diet. Österdahl and colleagues (2008) found that three weeks of a Palaeolithic-type diet resulted in significant decreases in systolic blood pressure, body mass, BMI and waist circumference in their small non-controlled trial of 14 participants of normal body mass. However, this study was limited by the decrease in total energy intake of participants during the Palaeolithic-type diet phase compared to their normal diet. This was despite participants being allowed ad libitum food from an 'allowed' food list. The observed reductions in blood pressure might therefore be due to the loss in body mass rather than the different nutrient composition of the Palaeolithic-type diet. To ensure against the confounding factor of loss of body mass, Frasetto and colleagues (2009) provided meals and snacks during the intervention phase to their nine sedentary, non-obese participants and monitored them daily so that calorie adjustments could be made if needed. Following 10 days of a Palaeolithic-type diet (preceded by seven days of 'ramp up' diets where potassium and fibre intake was gradually increased), participants showed small but significant reductions in blood pressure and improved arterial distension, decreased total cholesterol (-16%), LDL cholesterol (-22%) and triglycerides (-35%), decreased insulin secretion (area under curve, AUC) in a 2-hour oral glucose tolerance test (OGTT) and improved insulin sensitivity.

More recently, a study of 10 post-menopausal, obese women has been conducted, specifically looking at the effect of a Palaeolithic-type diet on hepatic (liver) fat (Ryberg et al., 2013). Post-menopausal women were chosen because after the menopause lipids tend to be moved from peripheral to central sites; this can lead to an excessive build-up of hepatic fat, which has been associated with increased CVD risk. The researchers drew on evidence linking carbohydrate and saturated fatty acid (SFA) intake with hepatic fat accumulation to hypothesise that a Palaeolithic-type diet (which partially replaces carbohydrate and SFA with protein and unsaturated fats) would reduce hepatic fat levels. Participants were again provided with prepared meals and snacks, which were matched in terms of total calorie intake to the participants' individual pre-trial diets, but they could also have ad libitum 'allowed' foods (i.e. lean meat, fish, eggs, nuts, seeds, fruit and vegetables). They followed the diet for five weeks, with weekly weight-monitoring sessions where they also completed food diaries. The results showed significant decreases in liver lipid content, liver insulin sensitivity, fasting plasma triglyceride, LDL cholesterol and glucose levels, and blood pressure. There was also a small but significant decrease in HDL cholesterol levels, although overall the LDL:HDL ratio improved. However, despite efforts to monitor weight, participants reduced their calorie intake during the trial (the prepared meals were not all finished) leading to significant decreases in body mass, BMI and waist circumference. Thus, the possibility that the favourable outcomes in hepatic fat were not due to the macronutrient proportions of the Palaeolithic-type diet cannot be ruled out.

Other studies have looked at the effects of the Palaeolithic-type diet among people with, or at heightened risk of, T2DM and CVD. These studies have compared the Palaeolithic-type diet with other diets recommended for these populations. Lindeberg and colleagues (2007) conducted a randomised controlled trial (RCT) with two groups of male patients with ischaemic heart disease and either T2DM or high blood glucose levels. One group received a Palaeolithic-type diet (n=14) and the other group received a 'Consensus' (Mediterranean-like) diet, based on whole grains, low-fat dairy products, vegetables, fruits, fish, oils and margarines. After 12 weeks, both diets resulted in significant decreases in body mass and waist circumferences, although for the latter measure the Palaeolithic-type diet gave a significantly greater decrease. The Palaeolithic group showed significantly greater improvement in glucose tolerance than the Consensus group (-26% in AUC glucose vs -7% following an OGTT). These decreases in AUC glucose were independent of the decreases in body mass and waist circumferences.

The same research group has also compared the effects of a Palaeolithic-type diet with an American Dietetic Association recommended diabetes diet, which is similar to the Mediterranean diet and advises that the majority of food should be naturally high in carbohydrates, particularly fibre (Jonsson et al., 2009). In a sample of 13 people with T2DM, a randomised cross-over trial was conducted whereby the sample was split into two groups, with one group following the Palaeolithic-type diet, the other following the diabetes diet. After three months on one diet, participants crossed over to follow the other diet for another three months. The Palaeolithic-type diet resulted in significantly greater decreases in plasma triglycerides, glycated haemoglobin (HbA1c, a measure that gives an indication of average plasma glucose concentration over a period of weeks/months) and blood pressure. The Palaeolithic diet also resulted in significantly greater increases in high density (so-called 'good') cholesterol. Both diets resulted in improved glucose tolerance but there were no significant differences between the two on the various measures of tolerance. Again however, despite being allowed ad libitum food, participants took in fewer calories while following the Palaeolithic diet. The researchers speculated that this was due to the satiating effects of the high water content in foods on the Palaeolithic-type diet and/or the higher proportion of protein (Jonsson et al., 2009).

Boers and colleagues (2014) have also compared the effects of a Palaeolithic-type diet with a healthy reference diet (this time based on the Dutch Health Council's guidance but similar to the Consensus diet in Lindeberg et al., 2007). Their study involved 34 participants who each exhibited at least two characteristics of metabolic syndrome. Participants were randomly assigned to either the Palaeolithic-type diet or the healthy reference diet and followed their assigned diet for two weeks. In an effort to prevent the loss in body mass that had limited previous studies, all food was prepared by the researcher and matched for total energy content. Unfortunately the Palaeolithic group did lose significantly more body mass (again, not all of the prepared food was consumed) but after adjusting for this, the significantly more favourable effects for the Palaeolithic-type diet in blood pressure, HDL cholesterol and plasma triglycerides remained.

Pastore, Brooks and Carbone (2015) compared the Palaeolithic-type diet with a 'Heart Healthy' diet (again similar to the Consensus diet) among 20 adults (10 male) who had recently been diagnosed with hypercholesterolemia but who were not taking medication for this. This trial was of relatively long duration: first, all participants followed the Heart Healthy diet for 4 months, then all switched to a Palaeolithic-type diet for four months. Participants received advice on each diet at the start of each diet phase and then prepared their own meals. Adherence was monitored bi-weekly via review of daily diet diaries and was reported to be good for each diet. The researchers focused only on the effects for cholesterol, lipids and body mass. The Heart Healthy diet resulted in significantly decreased body mass for men but not women, the Palaeolithic-type diet led to significant decreases for both men and women. Furthermore the Palaeolithic-type diet resulted in significantly lowered total cholesterol, LDL cholesterol, plasma triglycerides and increased HDL cholesterol independent of changes in body mass, relative to both baseline and the Heart Healthy diet.

Most recently, Otten and colleagues (2017) have assessed whether the addition of an aerobic and resistance training programme to a Paleolithic-type diet would enhance the beneficial effects of the diet on fat mass and metabolic control. In a randomised controlled trial involving 29 overweight adults (19 male) who had been diagnosed with T2DM within the last ten years, all participants were instructed to follow a Palaeolithic-type diet for 12 weeks. Half the sample received standard exercise recommendations (moderate activity for at least 30 minutes every day) while the other half received three 1-hour training sessions per week, combining aerobic and resistance exercises, for the duration of the study. Dietary intake was measured by self-reported weighed food diaries and energy expenditure was assessed over 7-day periods by accelerometers at baseline and 12 weeks. Contrary to expectations, the exercise programme did not result in improved glycaemic control or insulin sensitivity beyond the improvements found with the Palaeolithic-type diet alone, however the exercise group did show a significant improvement in their cardiovascular fitness which was not seen in the comparison group. Among men, the exercise training programme helped to preserve lean mass. Both groups showed significant reductions in body mass, fat mass, waist circumference, plasma triglycerides, blood pressure and fasting glucose levels after 12 weeks of following a Palaeolithic-type diet.

The small sample sizes of these trials obviously limit their power but it is notable that the observed effects have been consistent with the predictions of the mismatch concept. In terms of practical application, the studies showing heightened benefit from the Palaeolithic-type diet compared with other recommended diets are perhaps the most relevant. However, another limitation of the trials of the Palaeolithic-type diet is that they changed several aspects of participants' diets at once; further research is needed in order to see whether the beneficial effects observed are due to one particular dietary change (e.g. omitting dairy products) or if all the changes are needed in combination. This could be important to understand since excluding certain food groups can make diets harder to follow (Katz, 2005; U.S. News and World Report, 2015). In an additional paper from their cross-over design dietary trial, Jönsson and colleagues (2013) reported the qualitative comments from participants during each diet phase: more participants commented on difficulty adhering to the Palaeolithic-type diet (n = 10) compared to the diabetes diet (n = 3), mainly because it was more restrictive and entailed omitting cereal and dairy products, which the participants missed. None of the studies gave an indication of the long-term effects of the diet. On the other hand, participants in the cross-over trial noticed the greater effects of the Palaeolithic-type diet and some commented that they intended to carry on following the diet after the study (Jonsson et al, 2009). Boers and colleagues (2014) also reported that their participants were motivated to continue the Palaeolithic-type diet.

In the late 1980s Eaton and Konner developed their original proposal - to use the Palaeolithic lifestyle as a model for our own - into a book, 'The Paleolithic Prescription'[1], for a wider public readership (Eaton, Shostak & Konner, 1988). This made recommendations not only about diet but also activity regimes and general lifestyle factors, such as sleep. These recommendations were based, like those for the diet, on palaeontological evidence and anthropological studies of contemporary hunter-gatherer societies, which the authors used to make retrojections of

[1] In this thesis the British spelling 'Palaeolithic' has been used, however the US spelling is 'Paleolithic', which has in turn led to the shortened form 'Paleo'.

the amounts and types of activities Palaeolithic humans would have undertaken. The authors highlighted that ancestral activities were varied and vigorous intensity tasks were likely conducted on only a few days of the week with lighter days in between, like contemporary hunter-gatherers have been observed to do (Eaton, Shostak, et al., 1988). To emulate this pattern and the varieties of activity in modern high income society, Eaton and colleagues advocated a cross-training regime and suggested different exercises that would provide a variety of cardiovascular, strength and flexibility training. Since 1988 further palaeontological and anthropological studies have enabled more detailed estimations of strength and energy expenditure (Ruff, 2000), and aerobic power (Cordain et al., 1998). However, to date no clinical trials have been conducted specifically assessing an ancestral model of physical activity in a high income population. Nevertheless, it is widely accepted that, consistent with the mismatch concept, many people leading a typical high income society lifestyle need to spend less time in sedentary pursuits and increase the frequency and duration of their physical activity, including low and moderate intensity activity such as walking (Archer & Blair, 2011; Ekelund et al., 2015; Konner & Eaton, 2010).

2.1.6.3 The Paleo movement

The Palaeolithic model put forward by Eaton and Konner received little public attention, despite the publication of their 1988 book, until the 21st century when Loren Cordain, a health and exercise scientist, published 'The Paleo Diet' (Cordain, 2002). Cordain has since gone on to expand the Paleo Diet™ enterprise with more books, a website and blog (www.thepaleodiet.com), and Paleo food and exercise products. The Paleo Diet™ was largely based on Eaton and Konner's work, indeed Cordain and Eaton have collaborated on a number of papers since the late 1990s about the Palaeolithic model (e.g. Cordain et al., 1998). However, the Paleo Diet™ advocates a more conservative approach, excluding all cereals, legumes and dairy. Cordain justifies this stance by reasoning that legumes and cereal grains (particularly wholegrains) would rarely have been consumed before farming of these plants. And further, that they contain, in varying amounts depending on the variety, substances commonly known as 'antinutrients', such as lectins and phytates. These so-called 'antinutrients' are substances that prevent the body absorbing nutrients from food, for example phytic acid (the product of phytate digestion in the gut) molecules bind to minerals such as iron and zinc in the small intestine, inhibiting their uptake through the intestine wall (Cordain, 2014a). However, critics of the Paleo Diet™ have highlighted that analysis of dental plaque on fossil remains of early humans has revealed traces of legumes and cereals, thus refuting the claim that Palaeolithic people did not eat these foods (Warinner, 2013).

Furthermore, the ‘antinutrient’ components can be eliminated or reduced by thorough cooking, soaking, sprouting or fermenting (Liener, 1962). Cooking is known to have been a processing technique used by Palaeolithic people (Ragir, 2000), further supporting the conclusion that they would have consumed cereals and legumes. With regards to dairy products, Cordain argues that the there is a lack of conclusive evidence for beneficial effects of dairy and some indications that it is associated with harm, and therefore even people who can digest lactose should avoid it (Cordain, 2014b). Critics have argued that this neglects the evidence that humans are still evolving, since about one third of the world’s population are able to digest lactose (Ingram et al., 2009; Zuk, 2013). Eaton, Shostak and Konner (1988) take a more moderate approach proposing that for healthy people who are able to digest lactose, small amounts of dairy products can acceptably be included in the diet.

Despite these criticisms the Paleo Diet™ approach has been adopted and advocated by numerous food bloggers, celebrity chefs and health professionals, and in recent years has become increasingly well-known among the public. In the years 2012 and 2013, ‘paleo diet’ was the most searched for diet in the Google search engine worldwide (Google Trends, 2014). However, with the increasing popularity has come a wide range of interpretations of what is and is not ‘Paleo’, in terms of both diet and exercise. For example, some Paleo diet books suggest using an 80:20 rule, whereby 80% of the diet should follow Paleo ‘rules’ but 20% can consist of foods not available to hunter-gatherers (Green, 2014). Others have mis-interpreted the lack of cereals in many Paleo diets as synonymous with low carbohydrate diets (Scott, 2014a), illustrating a fundamental lack of awareness of the nutrient content of different foods. The varied interpretations have led to frustration for some Paleo advocates, who see a separation from the original scientific evidence upon which the mismatch hypothesis was founded (Scott, 2014a). Scott (2014a) cites the increasing commercialisation of the Paleo movement, demonstrated by the manufacture of Paleo energy bars and Paleo chocolate, as particularly contradictory of the original mismatch hypothesis, which was highlighting the difference between ancestral and modern diets. Scott (2014a) further provides anecdotal evidence that this has created public confusion and a belief that a healthy Paleo diet is only achievable by buying these products. Furthermore, the Paleo diet is often portrayed in the popular press (e.g. Oakley, 2015) as a short-term weight loss diet rather than the long-term healthy diet Eaton and Konner, and many Paleo advocates, actually propose. Although weight loss for many people in high income societies would be beneficial for their health, there is increasing awareness that maintenance of post-weight loss weight is poor (Sniehotta, Simpson, et al., 2014) and thus what are needed are behaviours that can be maintained in the long-term. With regards to physical activity, Paleo-related online forum discussions highlight confusion about what kind of exercise fits the Paleo model; for example, there are debates about whether or not Palaeolithic people would have engaged more in endurance running or short sprints and therefore which is 'bad' or 'good' for people today (e.g. Karoliina, 2011). Again, in many cases, these public discussions show a separation from any scientific evidence and, critics of the Paleo movement argue, are distracting from the important point that any increase in physical activity would be beneficial for most people in high income societies (Zuk, 2013).

The varied interpretations of the Palaeolithic model are potentially harmful to the mismatch concept since unscientific claims of some Paleo advocates can be the target of critics who go on to reject the entire mismatch concept (Deaner & Winegard, 2013; Scott, 2014a). The most common criticism levied, both at the mismatch concept and the Paleo industry, is that Palaeolithic people had low life expectancies, implying that they were not healthier than people today, and further that they would not be expected to develop the chronic diseases that are commonly associated with older age. While it is true that the life expectancy at birth of Palaeolithic people and modern hunter-gatherer societies is much lower than that of high income societies, this can largely be attributed to cultural advances: modern health care has increased survival rates during childbirth and infancy, housing and technology provide shelter from the weather and decrease risk of predator attack (Eaton, Cordain & Lindeberg, 2002). These authors contend that behavioural lifestyle choices have little effect on life expectancy at birth, reporting that eliminating the risk factors of the nine most prevalent chronic diseases would increase life expectancy at birth by only four years. It is thus more valid to compare age-matched adults in hunter-gatherer and high income societies, and this shows that both biomarker precursors and actual incidence of chronic diseases, such as T2DM and CVD, are rare in hunter-gatherers (Eaton, Cordain, et al., 2002).

A further criticism of the Palaeolithic model is that focusing only on the hunter-gatherer lifestyle of the Palaeolithic period neglects the evolutionary adaptations that have shaped us prior to and after this period and that taking a broader view of human evolution can give us a more accurate understanding of what we are and are not adapted for (Lieberman, 2013; Zuk, 2013). Our ancestors have lived in many different environments and their diets varied depending on seasonal and geographic availability meaning that humans have adapted over millions of years to tolerate a wide variety of foods in a range of macronutrient proportions (Garn & Leonard, 1989). It is thus somewhat simplistic to imagine that there was one ancestral diet that was optimal for human health and which we should all strive to consume.

Furthermore, our vastly different lifestyles today, compared with those of Palaeolithic humans, mean that even if there was one optimal Palaeolithic diet, it would not necessarily be appropriate to our needs today (Lieberman, 2013). However, what we can take from our knowledge of ancestral eating habits are the types of foods that the human digestive system was exposed to throughout our evolution and thus what it is likely to be adapted to digest efficiently (Katz, 2005). It is indisputable that our ancestors, right up until the mid-twentieth century, consumed a greater quantity of fibre and much lower amounts of simple sugars, trans-fats and salt than people in high income societies today (Garn & Leonard, 1989; Katz, 2005). Importantly, these factors in the modern diet are known to heighten risk of chronic disease (Katz, 2005; Lieberman, 2013). A final significant consideration in relation to making dietary recommendations for health purposes is that the diet needs to be maintainable, and excluding multiple food groups is likely to be both off-putting and detrimental to adherence (U.S. News and World Report, 2015).

A similar argument can be made for physical activity in that the activity levels and patterns of our ancestors varied depending on their physical environment and the availability of resources (Lieberman, 2013). What we can take from our knowledge of ancestral activity levels and patterns, however, is that up until the mid-twentieth century the majority of humans engaged in habitual activity at levels that were higher than many people in high income societies reach today (Lieberman, 2013). Furthermore, ancestral activity levels fall within the recommended levels for prevention of T2DM and CVD, whereas many people in high income societies fail to reach these recommended levels (Archer & Blair, 2011; Leonard, 2008).

2.1.7 Concluding remarks to section 2.1

The human genome evolved over thousands of years in environments where physical activity was necessarily linked to food procurement and available foods were mostly low quality (in terms of energy density). In contrast, High income society provides easily available, energy rich foods and a wealth of technology designed to eliminate physical exertion. There is good evidence to support the mismatch hypothesis, that the changes to the human environment seen in high income societies have occurred too rapidly for the human genome to adapt and that this mismatch between genes and environment places humans at increased risk of developing chronic diseases, such as T2DM and CVD. Furthermore, studies have shown that adopting a diet and physical activity levels that are closer to those which humans would have had up until the ‘Westernisation’ of society can successfully reduce an individual’s risk of developing T2DM and CVD. While some people advocate adopting dietary and physical activity practices that emulate those of Palaeolithic humans, this has some theoretical and practical problems. The mismatch hypothesis nonetheless provides context for understanding both current behaviour and the physiology that makes humans susceptible to chronic disease in high income society, which can help to guide decisions about promoting health today.

2.2 Supporting health behaviour change

The previous section highlighted the current low levels of physical activity and poor quality diets of the UK and other high income populations and explained how this is leading to a high prevalence of obesity and chronic, non-communicable disorders. In response, health researchers, practitioners and policy makers have sought to develop interventions that educate, motivate and support people to increase their activity levels and improve their dietary intake. Based on their aim, these interventions have been termed *behaviour change interventions*, defined as "coordinated sets of activities designed to change specified behaviour patterns" (Michie, van Stralen & West, 2011, p.1). Many behaviour change interventions have been implemented and evaluated over the previous few decades with varying success; the continued rise in physical inactivity, obesity and preventable disorders such as T2DM, however, indicates that existing interventions have not been effective enough and new approaches are needed. This section aims to provide an overview of the literature on designing health behaviour change interventions with a specific focus on physical activity and dietary intervention.

2.2.1 Health behaviour change interventions

A multitude of factors has been identified as determining health-related behaviour and various combinations of these factors have been organised in theoretical models that researchers have proposed to help explain why people behave the way they do. In their ecological approach to behaviour, Sallis and colleagues (2006) described how health-determining factors operate at intrapersonal, social, environmental, and policy levels. In 1979 the US Surgeon General's report on health promotion and disease prevention highlighted the importance of promoting individual lifestyle changes to improve health; following this, throughout the 1980s and 1990s researchers focused on developing interventions that targeted intrapersonal determinants of behaviour change (e.g. cognitions and emotions; Stokols, 1996). Individual-level models and theories of behaviour were developed, refined and widely used to help guide intervention development throughout this period (DiClemente, Crosby & Kegler, 2009). These models are still used today in intervention design; however, whereas formerly interventions were based on a single model or theory, nowadays constructs from several theories are often combined to form an intervention that is tailored to the population or behaviour of interest (Abraham & Michie, 2008; Michie, Campbell, Brown, West & Gainforth, 2014).

Over the past two decades intervention designers have become increasingly interested in the social and environmental determinants of behaviours, recognising that these external factors have the power to counter or support individual efforts to become healthier (DiClemente et al., 2009). That is not to say that intrapersonal determinants are no longer considered important or worthy of being targets for intervention, rather it is now widely accepted that simultaneous intervention at individual, social and environmental levels will have the most chance of successfully effecting behaviour change (Haskell et al., 2007; Sallis, Owen & Fisher, 2008). In the UK, multiple approaches operating at different levels have been and continue to be employed to try to improve dietary practices and physical activity. For example, at an environmental level, investment has been made in cycle to work schemes and improving cycle paths in an effort to increase active transport. At a social level, schemes have been initiated to support and reward schools and workplaces in becoming healthy communities (e.g. the National Healthy School Programme, the National Workplace Wellbeing Charter). The majority of interventions, however, still operate at an individual level, offering advice and support dependent on a specific need or needs that an individual holds (NICE, 2014). For example, the NHS Health Check scheme seeks to identify adults between the ages of 40 and 74 who are at increased risk of T2DM, CVD or kidney disease. Following their Health Check an individual should be given tailored advice by their general practitioner or practice nurse about how to manage their risk, regardless of the risk score they receive (i.e. even an individual who is categorised as at low risk of developing a disorder should be given healthy living advice). It has been argued that individual-level interventions are best suited to populations identified as having risk factors for ill health, since these people are likely to require the greater level of support that individual-level interventions can offer (McKinlay, 1995). From an economic perspective, individual-level interventions are often more costly and so reserving them for at-risk populations presents a better return for investment.

2.2.1.1 Intervention design

In the mid-2000s, several researchers highlighted a lack of translation of health interventions from research into practice and called for greater attention to be paid to intervention design (Glasgow, Klesges, Dzewaltowski, Bull & Estabrooks, 2004; Michie & Abraham, 2004). Specifically, poor choice of outcome measures, inadequate sample sizes, poor choice and reporting of intervention techniques, and lack of mediation analyses were reported to be preventing researchers and practitioners from assessing: whether interventions work; how well they work; and how they work (Michie & Abraham, 2004). These three factors are not only important for providers to know before they commission an intervention but are also crucial for researchers to understand in order to advance behavioural science. For example, without understanding the processes or causal mechanisms through which an intervention exerts a positive effect on a behaviour (i.e. *how* it works), future interventions with other populations will be less able to replicate the beneficial effects. By identifying the underlying processes that precede a change in behaviour, such as psychological changes, as well as active ingredients in an intervention (i.e. the techniques that effected change), intervention designers will be able to apply this knowledge to target other populations and behaviours.

Several guides to intervention design exist, for example, the PRECEDE-PROCEED approach (Green & Kreuter, 2005), Intervention Mapping (Bartholomew, Parcel & Kok, 1998), the Medical Research Council guidelines for developing and evaluating complex interventions (Craig et al., 2008), and the Behaviour Change Wheel (Michie, van Stralen, et al., 2011). A key tenet of these guides is adopting a systematic approach involving several stages and, although various guides differ in their emphasis, several procedures are commonly advocated: assessing the needs of the target population and identifying possible barriers to change; applying theories and drawing on evidence to select the modifiable factors that are likely to bring about behaviour change; and setting clear and comprehensive objectives. Intervention design is also highlighted as an iterative process, requiring pilot testing and revision of intervention components before formally evaluating the intervention as a whole (Abraham, 2012b; Green & Kreuter, 2005; Michie, van Stralen, et al., 2011). By adopting a systematic approach to intervention design it is hoped that designers will be better able to ensure interventions meet the needs of their target audiences and be less likely to overlook important constraints and relevant theories (Abraham, 2012b). Drawing on existing evidence and theories should also help prevent wasteful repetition of unsuccessful interventions or long research protocols to discover successful techniques that already exist (i.e. re-inventing the wheel; Michie et al., 2011).

The importance of a systematic approach not only applies to the planning of an intervention but also to the evaluation and reporting. Process and outcome measures need to directly address the objectives and hypothesised processes of change (identified from the theories being applied in the planning stages) in order for researchers to evaluate if and how their intervention worked (Kok & de Vries, 2015; Michie & Abraham, 2004; Michie et al., 2014). The advancement of behavioural science and public health also depends on the thorough and accurate reporting of interventions; without knowing the precise content of an intervention and which theories had been applied in its design, as well as the results from the evaluation, other researchers will be unable to critically appraise the validity and applicability of interventions or replicate effective interventions (Boutron, Moher, Altman, Schulz & Ravaud, 2008). Many reviews of interventions have highlighted, for example, that it is hard to tell from trial reports if and how theories have been applied during the design and implementation of interventions (Painter, Borba, Hynes, Mays & Glanz, 2008; Prestwich et al., 2014). To aid researchers in reporting their interventions, the Consolidated Standards of Reporting Trials (CONSORT) checklist was published, setting out 25 items that researchers should report in their publications of randomised controlled trials of non-pharmacologic interventions (Boutron et al., 2008). The 25 items cover key details from the background and rationale for the intervention, through the method, analysis and results, to the limitations and generalisability of the findings. Item five of the CONSORT statement stipulates that authors should describe "the interventions for each group with sufficient details to allow replication, including how and when they were actually administered"; in 2014 the Template for Intervention Description and Replication (TIDieR; Hoffman et al., 2014) was published to provide authors with further guidance on how to adequately describe an intervention. The TIDieR was developed by consensus of experts in a two-round Delphi survey and sets out 12 features of an intervention that should be reported in publications. An increasing number of academic journals are stipulating that any articles reporting interventions should include the CONSORT checklist and TIDieR items, which should improve the quality of publications and better enable replication of effective interventions.

2.2.1.2 Behaviour change theory in intervention design

Behaviour change theories describe the processes through which a given behaviour is brought about; that is, they provide explanations of why a behaviour does or does not occur and stipulate antecedents or determinants of behaviour (Michie et al., 2014). Theories thus provide helpful frameworks for intervention designers to identify potential mechanisms for changing behaviours. Interventions can then be designed to target the determinants of behaviour highlighted in the theories: changing these determinants will, theoretically, cause behaviour change (Hardeman et al., 2005). As will be discussed in section 2.2.1.3, specific strategies or 'behaviour change techniques' exist that can be employed to target the identified determinants. By helping researchers identify the mechanisms of change, theories also show which mediating factors (i.e. behavioural determinants) to assess in intervention evaluation (Kok, Schaalma, Ruiter, Van Empelen & Brug, 2004; Michie et al., 2014). It is then possible to determine whether an intervention influenced the theorised mediator(s) of change and if this in turn influenced behaviour. Should an intervention not result in the desired behaviour change, researchers would then be able to see if this was because the intervention did not affect the mediator(s) or because the mediator(s) did not affect behaviour as predicted (i.e. the theory was not upheld). This form of process evaluation is thus important for the refinement of behaviour change theory and, in turn, should lead to more effective interventions in future (Michie et al., 2014; Michie & Prestwich, 2010).

Applying theories does not, however, guarantee intervention effectiveness; theories are rarely tested in a way that enables them to be falsified and science is slow to modify or reject theories for which negating evidence has been found (Gigerenzer, 2010; Meehl, 1978). However, some authors contend that interventions which are based on theory are more likely to be effective than those which are not theory-based (Ammerman, Lindquist, Lohr & Hersey, 2002; Taylor, Conner & Lawton, 2012; Webb, Joseph, Yardley & Michie, 2010). Conclusive evidence of this is lacking, with some meta-analyses and reviews finding no evidence of increased effectiveness for interventions that are reported to be theory-based (Dombrowski et al., 2012; Prestwich et al., 2014). However, the lack of evidence may be due to poor reporting of when and how theory has been applied (Prestwich et al., 2014). For example, many reviews have been criticised for potentially categorising interventions that have systematically and comprehensively applied theory with those that have been loosely informed by certain elements of a theory, which does not allow a fair and rigorous test of theory (Michie & Prestwich, 2010). This also underlines the importance of thorough reporting of intervention trials (Boutron et al., 2008; Painter et al., 2008). Further research, when enough well-reported intervention trials have been published, is needed but until then the helpful guidance that theory can bring to intervention design and evaluation (as discussed above) provides good reason to believe that use of theory in intervention design is beneficial.

A problem that intervention designers face when trying to use theory, is choosing from the vast array of behavioural theories that exists which would be most appropriate for their particular purpose. Some behavioural determinants are contained within multiple theories and no single theory includes all possible determining factors (Abraham, 2012b). The situation is further complicated by the fact that different behaviours and target populations will be influenced by different determining factors and processes (Hardeman et al., 2005). Conducting exploratory research with target populations and drawing on evidence from previous research with similar populations, about similar target behaviours, can help researchers to identify likely determinants of behaviour change; they can then choose theories that include these determinants (Green & Kreuter, 2005; Kok et al., 2004). Due to the complex nature of behaviour - meaning that multiple factors will play a role in determining any one behaviour - a combination of theories may need to be applied in order to address all relevant determinants (Abraham, 2012b).

2.2.1.3 Behaviour change techniques

A behaviour change technique (BCT) is "a systematic procedure included as an active component of an intervention designed to change behaviour" (Michie & Johnston, 2013, p.182). Over the past decade researchers have compiled taxonomies of BCTs that have been used in interventions to change a range of health behaviours, with the latest taxonomy including 93 different BCTs (Abraham & Michie, 2008; Michie, Ashford, et al., 2011; Michie et al., 2013). While these taxonomies are helpful for raising awareness of the options available, they do not indicate which BCTs are most effective for different behavioural determinants or target populations. For any determining factor a variety of BCTs may exist; for example, Abraham (2012) identified 10 different techniques designed to increase a person's self-efficacy (i.e. their belief in their ability to accomplish a task; Bandura, 1997), a determinant often found to cause successful behaviour change. It is left to researchers to decide which BCTs to employ and, again, exploratory research and reference to evidence from previous interventions can help. For example, a systematic review of reviews on dietary and physical activity interventions reported that the BCT 'social support' was associated with increased weight loss (Greaves et al., 2011). This review also found that 'providing instruction' and self-regulatory techniques such as 'goal setting' and 'self-monitoring of behaviour' were associated with dietary and physical activity change (Greaves et al., 2011); this supported an earlier meta-regression which found that interventions that prompted self-monitoring brought about greater improvement in physical activity and healthy eating (Michie, Abraham, Whittington, McAteer & Gupta, 2009). For some BCTs, however, not enough evidence exists yet for their effectiveness to be evaluated in reviews and so researchers may need to rely on their knowledge of the target audience and intuition.

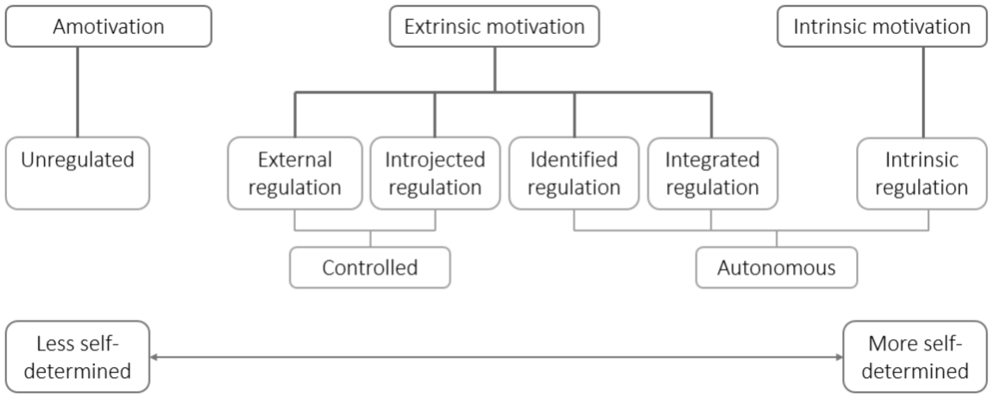
A further point to note about BCTs is that, although their content (i.e. what should be delivered) is defined in taxonomies, the way in which they should be delivered can vary. For example, the BCT 'providing instruction' could be delivered in a leaflet, on a website, via a television programme, or in-person by a health professional. The effects of different modes of delivery on intervention effectiveness has received relatively little attention in research. Greaves and colleagues (2011) commented in their systematic review on dietary and physical activity interventions that there is supportive evidence for a range of delivery modes, with no one mode being clearly linked with better effectiveness. However, Dombrowski, O'Carroll and Williams (2016) have recently argued that the form of delivery is an active ingredient of interventions which can affect their ultimate success in promoting behaviour change. Later sections in this literature review will consider how delivery mode can influence initial uptake of and engagement with interventions, which in turn will impact on an intervention's real-life effectiveness.

***

The research presented in this thesis explores the novel approach of using the concept of an evolutionary mismatch in a health behaviour change intervention to promote physical activity and consumption of a healthy diet. The idea behind using the mismatch concept was that it might provide a stronger rationale for the need to adopt healthy behaviours to people for whom standard health information seems not to provide sufficient rationale to change; this is because the mismatch concept explains not only *what* lifestyle factors cause disease but also *why* these factors cause disease. Furthermore, the mismatch concept provides an over-arching framework for introducing information on human evolution, physiology and behaviour, thus enabling more in-depth information to be delivered in a cohesive manner. This could lead to people gaining a greater knowledge of how to maintain a healthy lifestyle. The theories applied in the development and evaluation of the intervention (discussed in the following sections - 2.2.2 and 2.2.3) were selected based on their specific inclusion of these determinants (rationale and knowledge), as well as the strong supporting evidence for applying them to physical activity and dietary behaviour. As highlighted in section 2.2.1.2, due to the complex nature of behaviour a combination of theories is now acknowledged to be appropriate to investigate multiple potential determinants (Abraham, 2012b).

2.2.2 Self-determination theory

One theory that is increasingly being applied in health intervention design is self-determination theory (SDT). SDT is a meta-theory of human motivation based around the belief that humans have evolved inner resources for behavioural self-regulation and an innate propensity to strive for psychological development (Deci & Ryan, 1985; Deci & Ryan, 2008a; Ryan & Deci, 2000). In SDT, motivation is seen to exist on a continuum from amotivation (i.e. an absence of motivation) through increasingly self-determined forms to intrinsic motivation (i.e. motivation due to inherent interest and enjoyment in the act; Deci & Ryan, 2008a). Figure 2.1 illustrates the motivation continuum, showing the three main categories of motivation – amotivation, extrinsic and intrinsic – as well as the four sub-categories of extrinsic motivation. The least self-determined form of extrinsic motivation is external regulation, in which behaviours are enacted to avoid punishment or gain a reward. This is followed on the continuum by introjected regulation, whereby behaviour is still largely externally controlled but the individual has also formed internal representations of the controlling external factors (e.g. acting to avoid guilt, gain approval or because one feels one *should*). Next is identified regulation, in which behaviours are undertaken because their outcomes are valued by the individual (e.g. going to the gym because one wants to lower one's risk of CVD). This form of regulation is classed as autonomous because the individual has identified with the activity's value, yet it is still deemed to be extrinsic as it is separate from one's own values (i.e. it is the outcomes that are valued by the individual rather than the behaviour per se). Integrated regulation is also an extrinsic yet autonomous form of motivation and occurs when behaviour is enacted because it defines one's sense of self (e.g. 'I run because I'm a runner'). Integrated regulation is the most self-determined form of external regulation and, while it is fully integrated within the self, it is distinct from intrinsic motivation as the behaviour is not necessarily undertaken for the enjoyment it brings.



Adapted from Deci & Ryan, 2008a.

Figure 2.1 The types of motivation and regulation within self-determination theory, and their placement along the continuum of relative self-determination.

A central tenet of SDT is that the type or quality of motivation will be more important for predicting psychological and behavioural outcomes than the amount of motivation (Deci & Ryan, 2008b). More self-determined forms of motivation are seen to be of better quality, predicting more positive outcomes such as behavioural persistence, adherence and increased effort, as well as psychological well-being (Deci & Ryan, 2008a). It is therefore desirable, in a health behaviour change context, to try to promote more self-determined motivation for healthy behaviour since this will result in more engagement with and maintenance of the behaviour (Santos, Silva & Teixeira, 2016). Internalisation is the process through which external regulations can be transformed into more internal, and thus more self-determined, regulations (Deci, Eghrari, Patrick & Leone, 1994). When internalisation takes place optimally, externally regulating or controlling factors (e.g. a partner or health professional making a person omit highly sugary foods from their diet) are assimilated with one's own values so that the behaviour is perceived to have come from a sense of self (e.g. an individual omitting high-sugar foods because they value their health or because they enjoy eating healthier foods). SDT proposes that individuals have a natural tendency to internalise regulation for behaviours they enact regularly, since this will be adaptive for their functioning and help maintain their well-being (Deci et al., 1994). However, the social environment acts as a limiting factor, either fostering or hindering this innate tendency for internalisation (Deci et al., 1994; Deci & Ryan, 2008a). The degree to which an environment fosters internalisation is dependent on its ability to satisfy three basic psychological needs that, in SDT, are considered to be present in every person: the needs for autonomy, competence and relatedness. The need for autonomy refers to a need to feel that one's actions come from oneself, i.e. that actions are self-regulated and that the individual has control over whether or not they act (Ryan & Deci, 2006). The need for competence reflects a need to feel capable and effective as well as perceiving that one has opportunities in which to demonstrate one's capabilities (Deci & Ryan, 2008a; Ryan & Deci, 2000). Finally, the need for relatedness is a need to feel connected to, cared for by and valued by other individuals (Deci & Ryan, 2008a). When all three needs are satisfied, intrinsic motivation is allowed to thrive (Ryan & Deci, 2000). However, it should be noted that intrinsic motivation can occur when not all of the needs are satisfied. The need for relatedness, in particular, is thought to play a less important role than autonomy and competence in maintaining intrinsic motivation (Vansteenkiste, Williams & Resnicow, 2012); for example, people often engage in activities that they find enjoyable or interesting on their own (e.g. reading).

2.2.2.1 Promoting internalisation

In order to facilitate the internalisation of regulation, intervention designers can seek to manipulate environmental factors that will support the basic psychological needs. Early experimental work by Deci and colleagues (1994) showed that providing individuals with a meaningful rationale for acting, acknowledging their feelings and offering choices in a non-controlling manner (e.g. "*If you are willing to continue, all you need to do is press the start button*" vs. "*You should press the start button now*") all helped to provide an autonomy supportive environment leading to greater internalisation. This study involved a large sample of undergraduates (N = 192) whose task was to complete a boring visual perception task at a computer. When at least two of the autonomy supporting factors were present, motivation for the task was more likely to be integrated, whereas when one or no factors were present, motivation was most likely to be introjected (i.e. less self-determined). This pioneering study was supported by a similar experimental study involving an uninteresting language learning task for college students (Reeve, Jang, Hardre & Omura, 2002). Providing a rationale for the task ("[*it] offers you the opportunity to gain a skill that will be very handy when you become a classroom teacher*"), using non-controlling language and acknowledging participants' feelings led to greater perceived autonomy support, more self-determined motivation for the task (specifically, identified regulation) and greater self-reported and researcher-rated effort put into the task (Reeve et al., 2002). More recently, a study by Savard and colleagues (2013) involving an interpersonal skills workshop for female adolescents with behavioural problems has added ecological validity to the findings of the experimental studies by Deci et al. (1994) and Reeve et al. (2002). These studies have looked at the combined effect of various strategies to support autonomy; little research has investigated whether providing, say, a meaningful rationale in isolation would be sufficient to promote internalisation. Patall, Dent, Oyer and Wynn (2013) used hierarchical linear modelling to look at the unique effect of various autonomy supporting teaching practices on students' need satisfaction and perceptions of the course. Only provision of choice and showing empathy uniquely enhanced autonomy need satisfaction, although rationale provision was positively associated with autonomy need satisfaction and uniquely predicted perceived value of the course. However, this study used data from one point in time, so causal relations cannot be inferred. It also relied on students' self-reports of the degree to which each teaching practice had been delivered; some practices may have influenced autonomy but not have been perceived by the students. Further experimental and longitudinal research is needed to investigate the effects of different autonomy support techniques delivered in isolation.

More research is also needed on how to deliver the autonomy supporting techniques. For example, Vansteenkiste and colleagues (2004) have suggested that rationales for a behaviour or task need to be specific, since they found a vague and abstract rationale (*"it's important for your future")* did not lead to increased effort in an activity yet participants did display increased introjected regulation. The authors concluded that the vague rationale had a motivating effect from the sense of anxiety it elicited when participants did not increase their effort in the task. It has also been highlighted that choices can be offered in both autonomy supporting and controlling manners (Vansteenkiste et al., 2012). For example, a health professional could offer treatments in a judgemental way ("It is up to you to decide whether or not to take the medication but I think it would be unwise not to") or offer a wide variety of treatments with no guidance, either of which is likely to make a person anxious, which might negate the need-supporting effect of providing a choice. There is also relatively little in the

SDT literature on how to support competence and relatedness. Patrick and Williams (2012) advise that providing accurate feedback in a non-judgemental manner, identifying barriers to action and setting plans that are challenging yet achievable can help support competence, while providing unconditional positive regard and a friendly interpersonal environment will support relatedness. However, research is needed to test these techniques experimentally and in applied settings (Vansteenkiste et al., 2012).

2.2.2.2 SDT-based interventions

There is a large body of evidence to support the concepts and models proposed in SDT across various life domains, including education (Standage, Duda & Ntoumanis, 2005), work (Deci, Olafsen & Ryan, 2017), physical activity (Chatzisarantis, Hagger & Smith, 2007), diet (Pelletier, Dion, Slovinec-D'Angelo & Reid, 2004) and other health-related behaviours such as adherence to medication regimes (Williams, Lynch & Glasgow, 2007). While most of the SDT literature has sought to test the theory in experimental studies or population datasets, increasingly SDT concepts are providing the basis for applied work in the field of behaviour change (Vansteenkiste et al., 2012). For example, clinical trials have investigated the efficacy of SDT-based interventions for behaviour change in the fields of weight loss (e.g. Silva et al., 2010), diet (e.g. Leblanc et al., 2016), physical activity (e.g. Chatzisarantis & Hagger, 2009) and tobacco cessation (e.g. Williams, Niemiec, Patrick, Ryan & Deci, 2009). These interventions have brought about positive behavioural outcomes by increasing internalisation and autonomy for the relevant behaviours.

The motivation continuum and concept of internalisation are of particular practical value to health intervention designers since they provide guidance for promoting the adoption and long-term maintenance of behaviours that are not perceived to be interesting or enjoyable, at least initially, by the target audience. Although health behaviour changes (such as increasing physical activity or cutting down on sugary foods) are unlikely to be intrinsically motivated, internalisation can lead to other autonomous forms of motivation (i.e. identified and integrated) that can still bring about positive outcomes, such as sustained engagement with the behaviour (Santos et al., 2016; Vansteenkiste et al., 2018). Furthermore SDT offers insight into the two distinct problems facing health practitioners: initial behaviour change and maintenance of new healthy behaviours. Behavioural maintenance in relation to weight loss has been highlighted recently as a particular concern, with the majority of people who have successfully lost weight in non-surgical interventions regaining all the weight lost over the following three to five years (Greaves, Poltawski, Garside & Briscoe, 2017). Taking a SDT perspective, initial behaviour change is likely to be made from controlled motivation, for example, feeling pressure from a health professional (external regulation) or wanting to avoid guilt if they do not successfully lose weight in a research trial and feel that this could ruin the study (introjected regulation). Or the individual might be working towards an extrinsic goal, such as losing weight to try to become more attractive. These external regulations are unlikely to overcome barriers the individual may face in maintaining the behaviour and thus relapse can occur. However, if the intervention can promote internalisation, the individual will come to personally value the new behaviour and be more likely to sustain it over time. To a certain extent internalisation can occur simply from enacting the behaviour (Ng et al., 2012), for example someone might start going swimming in order to please their partner but over time they come to feel the physical and health benefits and gain a more autonomous regulation for swimming. However, providing a need-supportive environment within an intervention will increase the likelihood of internalisation (Ng et al., 2012).

2.2.3 The theory of planned behaviour

Another commonly cited theory in health behaviour change is the theory of planned behaviour (TPB; Ajzen, 1985). In the TPB, behaviour is predicted by an individual's intention to act and their perceived behavioural control (PBC). Intentions are in turn determined by an individual's attitudes towards the behaviour, their perceived norms of performing the behaviour, and their PBC (i.e. PBC has both a direct effect on behaviour and an indirect effect through intention). The strength and accessibility of behavioural, normative and control beliefs will determine attitudes, subjective norms and PBC. The model describing the relationships between these factors is depicted in Figure 2.2. As shown in the Figure, feedback loops are hypothesised to exist whereby current behaviour influences future beliefs (Ajzen, 2015).

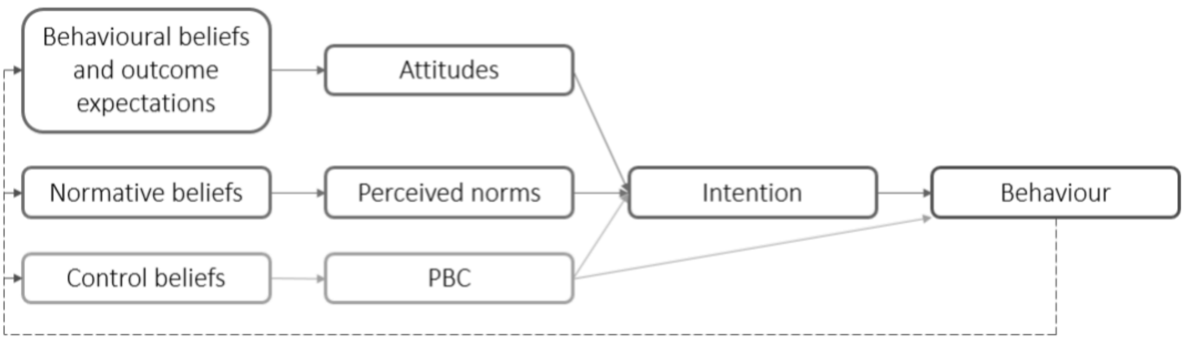


Figure 2.2 Model of the theory of planned behaviour

The TPB was developed from the theory of reasoned action (Fishbein & Ajzen, 1975), which did not include PBC. Ajzen (2002) has reported that PBC is conceptually similar to self-efficacy (SE) and several researchers have used validated SE measures in place of PBC measures. However, the majority of researchers now view PBC as a multidimensional construct composed of both

SE (i.e. perceived difficulty) and perceived controllability (Ajzen, 2002; Conner & Sparks, 2005). Attitudes and norms are also seen as multidimensional constructs (Conner & Sparks, 2005): attitudes can be instrumental (e.g. useful-useless) or affective (e.g. pleasant-unpleasant); social norms may be descriptive (i.e. perceptions of others' behaviour) or injunctive (i.e. perceptions of what behaviours will elicit approval/disapproval from others).

Behavioural, normative and control beliefs are shaped by many individual and socio-environmental factors, including past behaviour (as mentioned), knowledge, age, culture etc. A particularly salient factor for health interventions is factual information or knowledge: it is assumed that only when people are well-informed can they act to protect their health (Naidoo & Wills, 2005; Nutbeam, 2000). However, it is clear that accurate knowledge is not sufficient to ensure people will adopt healthy behaviours; for example, the majority of the British public are aware that eating five portions of fruit and vegetables a day would be beneficial for their health (Roberts & Marvin, 2011), yet only about a quarter (26%) actually consume this recommended intake (Fuller, Mindell & Prior, 2017). Ajzen and colleagues (2011) have used the TPB to explain why this knowledge-behaviour discrepancy might exist: they posit that knowledge is only influential to behaviour if it shapes the salient beliefs for that behaviour (Ajzen et al., 2011). In this respect, information accuracy is neither necessary nor sufficient for behavioural decision making – it is the subjectively held information (beliefs) that matters. Ajzen et al. (2011) point out that tests of knowledge often assess general facts rather than salient information that is used to decide when and how to act. The implications for health education therefore are to identify the accessible beliefs for the behaviour of interest and provide information to counter ill-founded beliefs that dissuade people from acting and provide information to support encouraging beliefs.

2.2.3.1 TPB-based interventions

In the field of health behaviour change, the TPB has been widely cited and applied in intervention design (Ajzen, 2011). A meta-analysis of 237 prospective tests of the TPB, involving a variety of health behaviours, found the predicted relationships were upheld, with intention showing the strongest relationship with behaviour (p = 43; McEachan, Conner, Taylor & Lawton, 2011). Attitudes, perceived norms and PBC together explained 44.3% of the variance in intentions, and PBC and intention combined predicted 19.3% of the variance in behaviour (McEachan et al., 2011). Behaviour type was found to moderate the model, with the TPB variables predicting the most amount of variance for physical activity and diet behaviours (23.9% and 21.2%, respectively). The results from this meta-analysis and other reviews of the TPB have been interpreted differently by different researchers. Sniehotta, Presseau and

Araújo-Soares (2014) have proposed that the TPB's limited predictive power is symptomatic of the theory's lack of comprehensiveness; many other variables have been identified that partly determine intentions and behaviour and yet they are excluded from the TPB for reasons of parsimony (Sniehotta, Presseau, et al., 2014). Abraham (2014) also acknowledges this limitation yet still counts the TPB as a useful part of his 'theoretical toolkit' as a practising health psychologist. Indeed no completely comprehensive behavioural theory yet exists and so intervention designers should draw on a range of theories depending on the factors that needs assessment and previous research have suggested might be instrumental in behaviour change for the target population and behaviour (see section 2.2.1.2). It is also worth noting that, although the TPB variables may not always have a large effect on behaviour, even small changes in behaviour can result in clinically meaningful changes in health at the population level (Abraham, 2014). For example, a meta-analysis of experimental tests investigating the effect of intentions on behaviour found that medium to large changes in intention (d = 0.66) led to small to medium changes in behaviour (d = 0.36; Webb & Sheeran, 2006), which are typical of health promotion interventions that are deemed to be effective (Fitzgibbon et al., 2007).

2.2.4 Turning motivations and intentions into action

SDT and the TPB both offer possible explanations of how an intervention that educates people about the ways in which their lifestyle can affect their health could influence their behaviour: either by providing a meaningful rationale, and in turn promoting more self-determined motivation, for healthy behaviour change; or by altering beliefs, attitudes and perceptions of control, which could prompt intentions to change. However, it is well-recognised that people often fail to act on their motivations and intentions (Orbell & Sheeran, 1998; Webb & Sheeran, 2006). This can be due to factors outside the control of the individual, for example, heavy traffic might prevent someone getting to the gym before it closes after work. Yet there are also what Orbell and Sheeran (1998) have termed the 'inclined abstainers' - people who have both the means and motivation to act but fail to do so. This intention-behaviour gap has sparked much research, particularly in health psychology, and several techniques have been investigated to help people bridge the gap. So far, the most effective techniques found to help people act on their physical activity and dietary intentions and motivations are self-regulatory skills such as goal setting, action planning, coping planning and self-monitoring (Bélanger-Gravel, Godin & Amireault, 2013; Glanz & Bishop, 2010; Nurmi, Hagger, Haukkala, Araújo-Soares & Hankonen, 2016; Schwarzer, 2008). Self-regulation refers to an individual's efforts to avoid habitual or innate responses to situational cues by controlling their thoughts, feelings and task performances, and thus overcome obstacles to enacting desired behaviours (Baumeister, Gailliot, DeWall & Oaten, 2006; Sniehotta, Schwarzer, Scholz & Schüz, 2005). Several reviews and meta-analyses have shown that interventions including self-regulatory techniques have increased effectiveness in terms of weight loss, improved diet and physical activity (Bélanger-Gravel et al., 2013; Dombrowski et al., 2012; Greaves et al., 2011; Michie et al., 2009). These techniques seem to be particularly effective when used in combination, for example, goal setting with self-monitoring (Dombrowski et al., 2012; Michie et al., 2009).

An intervention that promotes intentions and self-determined motivation for behaviour change, and that also includes self-regulatory techniques might have a greater impact on behaviour than one that relies only on changing intention/motivation as means to behaviour change. An example of one such intervention comes from Darker, French, Eves and Sniehotta (2009) who designed and evaluated a brief (one week) intervention to increase walking among sedentary adults. The intervention included reflective activities to help boost participants' PBC and intentions for walking, as well as goal setting, action planning and coping planning tasks. As a result of the intervention, changes of large effect size were found in attitudes ($d = 0.98$), PBC ($d = 1.86$) and intention ($d = 1.55$). Effects on self-regulatory behaviours were not reported. There was also a 60% increase in objectively measured time spent walking ($d = 0.90$), an improvement that was mostly maintained at one month follow-up. In this study, PBC was found to be the main mediator for intervention effects on behaviour (Darker et al., 2009). However, as all intervention components were delivered simultaneously it was not possible to determine the specific effects of the PBC, intention and self-regulation parts of the intervention (i.e. PBC may not have had such a strong effect on behaviour had the action planning techniques, say, not been present).

2.2.5 Engagement with health interventions

Any health intervention will only be effective if the target population take it up and engage with the BCTs included. Most health behaviour change interventions are first tested under conditions that aim to ensure the validity of the outcome assessments (e.g. exposure to intervention materials is regulated and incentives are used to make sure enough people participate; Albarracín, Durantini, Earl, Gunnoe & Leeper, 2008). This provides a necessary understanding of the efficacy of the intervention (Singal, Higgins & Waljee, 2014) but not how effective it will be when implemented in 'real world' conditions, where individuals can choose whether or not to engage with an intervention. Often efficacious interventions fail to reach the people most in need of them (e.g. those most at risk of developing a disorder) as they fail to interest these individuals (Albarracín et al., 2008; Greaves, 2015). There are many reasons why people might not be interested in an intervention. For example, an individual may not perceive himself/herself as being at risk or in need of help (Johnson, Cooke, Croker & Wardle, 2008) and therefore not see the intervention as personally relevant. A person may not like the proposed behaviour change (or perceived target behaviour) or be sceptical about the benefits it can bring, or they may in general not be interested in the topic (for example, someone may not be interested in either their health or diet). Failure to maintain people's engagement can also undermine the ability of an intervention to effect behaviour change (Greaves, 2015). Therefore a further, though often overlooked, consideration in intervention design is the inclusion of strategies to encourage and maintain engagement – these strategies are sometimes called meta-interventions (Albarracín et al., 2008).

2.2.5.1 Promoting interest to increase engagement

Although lack of engagement with an intervention may also come from lack of exposure or access (i.e. a problem of dissemination of the intervention) and practical factors limiting an individual's ability to engage (e.g. lack of time), intervention designers have more control over the ability of an intervention to interest the target population. Therefore focusing on strategies to promote interest seems a prudent approach to increase engagement and effectiveness. Interest is an emotion that functions to motivate an individual to explore and learn, and thereby build skills (Katz, Assor, Kanat-Maymon & Bereby-Meyer, 2006; Silvia, 2006). Experimental research, mostly involving undergraduate students, has demonstrated that interest promotes increased cognitive effort, cognitive elaboration (i.e. deeper thought), greater persistence in tasks (Silvia, Henson & Templin, 2009; Thoman, Smith & Silvia, 2011), and is also strongly related to emotional engagement (Sun & Rueda, 2012). This would suggest that if a health intervention can generate interest among target users of the intervention, they will be more likely to learn its educational content and continue to persist with behavioural tasks (such as self-monitoring or trying new health behaviours) included in the intervention. However, there is little research investigating the role of interest in health interventions. Since most interventions are complex (involving a range of educational and behavioural elements) and require sustained engagement, the role of interest may also be complex; for example, interest may be critical at the early stages of adopting an intervention, but self-efficacy in engaging with the intervention may be more important for long-term adherence.

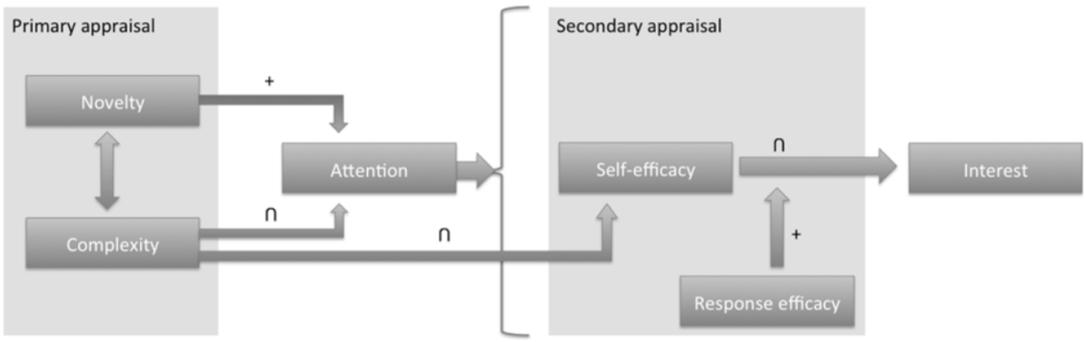
Crutzen and colleagues have conducted some pioneering research on the role of interest in health interventions (Crutzen, Ruiter & de Vries, 2014). They have focused on internet-delivered interventions and highlight that interest may play a particularly relevant part in these since engagement with the intervention tends to be self-directed and not subject to other people waiting for and judging the individual's responses (such as in face-to-face communication) – thus the individual is more likely to selectively engage based on feelings of interest (Crutzen & Ruiter, 2015). In a series of three experiments, Crutzen et al. (2014) compared the effects of manipulating a website and invitation to use the website (delivered as a Google AdWords advert) in order to increase interest or enjoyment. In order to generate interest, the invitations and website employed challenging questions as headers and then either stated that the website would provide comprehensible answers (invitations) or provided the answers immediately below the headers in a clear and coherent way (website). In order to promote enjoyment, the invitation explicitly stated that the website was enjoyable and cheerful non-threatening pictures were added to the website. In comparison to the enjoyment-arousing invitation and website, the interest-arousing conditions promoted increased likelihood of visiting the website and sustained use of the website (in terms of number of pages visited). The authors concluded that generating interest is a promising strategy to increase use of interventions and thus potentially enhance their public health impact (Crutzen et al., 2014).

2.2.5.2 The appraisal theory of interest

Interest varies both between-persons (e.g. what one person finds interesting, another will find dull) and within-persons (e.g. an initially interesting book may over time become boring or frustrating), which makes it difficult to develop general theories about what will be interesting (Silvia, 2008). Drawing on appraisal theories of emotion (which propose that emotions come from subjective evaluations of situations or objects; Lazarus, 1991) and his own research, Silvia (2005, 2006) has proposed that interest comes from two sequential appraisals. The first appraisal is of the stimulus' novelty and complexity (i.e. how new or unexpected and hard to process or obscure the object is). The second appraisal is of its comprehensibility, where an individual evaluates whether they have the skills and resources to cope with the stimulus (e.g. do they feel able to learn the information in a leaflet on healthy eating). In the primary appraisal, novelty is theorised to have a simple, positive relationship with attention: the more novel a stimulus, the more likely an individual will be to direct their attention to it. Complexity, however, is thought to have an inverted-U shaped relationship with attention: a stimulus needs to have sufficient complexity to not be immediately obvious yet not be too complex to process. If attention is directed to the stimulus after the primary appraisal, interest will result if the stimulus is then perceived during the secondary appraisal to be within an individual's coping potential (i.e. having the skills and resources to understand the stimulus; Silvia, 2006; 2008).

The experimental research supporting Silvia's appraisal theory of interest has mostly involved art and educational texts as stimuli (e.g. Sadoski, 2001; Silvia, 2005, 2010; Silvia et al., 2009; Thoman et al., 2011), however, the theory could be usefully applied when developing health behaviour change interventions. Crutzen and Ruiter (2015) have expanded the appraisal theory for use in health interventions, suggesting that the secondary appraisal will be determined by an individual's self-efficacy for the promoted behaviour change and their response efficacy (i.e. whether the behaviour proposed in the intervention is thought to be likely to have a positive effect). The latter is theorised to have a simple, positive relationship with interest, but self-efficacy is thought to have an inverted-U shaped relationship, whereby if the advocated behaviour is deemed to be too easy this will not stimulate interest yet if it is deemed too difficult, a person will be unlikely to be interested in engaging (Crutzen & Ruiter, 2015). This theory is illustrated in Figure 2.3. Research is still needed to test the proposed relationships of the theory and also to determine optimal levels of the included constructs for generating interest.

Figure 2.3 An appraisal model of interest in behaviour change interventions.



Source: Crutzen & Ruiter (2015)
Note: A plus sign indicates a positive relationship, an inverted U indicates an inverted U-shaped relationship.

The appraisal theories of interest have implications for health behaviour change interventions both in terms of gaining initial engagement and for maintain engagement. As demonstrated in the health website studies (discussed in section 2.2.5.1; Crutzen et al., 2014), increasing interest by manipulating novelty and complexity (e.g. through using a question-answer format) and ensuring comprehensibility (e.g. by using simple, coherent language and layout) can increase initial uptake and short-term engagement with an intervention. For longer-term, sustained engagement the appraisal theory would imply that intervention content will need to be dynamic, changing to ensure novelty, complexity and comprehensibility remain as the user's knowledge and ability grows. For example, once an individual has engaged with and understood information on an intervention website, they may be unlikely to find that information interesting any more since it will no longer be novel and likely will be appraised as lacking complexity (Silvia, 2006). Regularly adding new informational content could improve the likelihood of people returning to the website. Gaining new knowledge on a subject might also make a person more likely to notice subtleties in related information, and thus perceive more 'new' information on this subject in their environment (Silvia, 2006). This helps to explain enduring interests – for example, the more a person learns about nutrition, the more able they are to identify nutrition-related stimuli in their everyday life, perceiving old stimuli in a new light. However, experimental and applied research on maintaining interest is lacking.

2.2.6 Communication in health interventions

The way in which an intervention's content is communicated to the target population can play a key role in creating interest, promoting uptake and preventing attrition (Cappella, 2006), as well as influencing how effective health behaviour change information (e.g. persuasive information regarding risks of unhealthy behaviours, instructions on how to perform healthy activities or self-regulatory actions) is at altering determinants of behaviour change (Abraham & Kools, 2012; National Institutes of Health, 2002). Communication theories can be usefully applied in designing health interventions in order to increase the likelihood that the intervention messages are transmitted to the audience as intended and are effective in promoting (desired) cognitive change (Robertson, 2008). Communication theories complement behaviour change theories; the former specify the mechanism by which cognitions (e.g. knowledge, attitudes) can change, while the latter specify which cognitions to target in order to effect behaviour change (Cappella, 2006). Several communication theories exist but the elaboration likelihood model (ELM; Petty & Cacioppo, 1986) will be considered here. The ELM focuses upon the cognitive processes that lead to acceptance of a message and provides more detail on factors to consider when constructing a message. It is considered here for its particular attention to promoting lasting changes in understanding and behaviour.

2.2.6.1 The Elaboration Likelihood Model

The ELM is an information processing model of communication which posits that there are two possible routes through which information can be processed to bring about persuasion (Petty & Cacioppo, 1986). In this theory, persuasion is conceptualised as the comprehension, acceptance and retention of a message and is seen as main determinant of attitudes (Petty, Heesacker & Hughes, 1997). The two routes to persuasion are peripheral processing and central processing, which refer to the level of scrutiny given to a message by the reader/receiver. In peripheral processing, relatively little attention is paid to a message and short-cut cues (heuristics) are used to understand the message content; for example, a person may accept a celebrity-endorsed health message on the basis that they like and trust the celebrity. In central processing, a message is closely examined to understand and critique the quality of the argument. Various factors, including both message and receiver characteristics, will influence the type of processing employed and it is possible for both types of processing to occur at once (Cappella, 2006). The greater degree to which central processing is employed, the more cognitive elaboration occurs; cognitive elaboration being the process of integrating new information with existing knowledge, which results in better retention, recall and resistance to change of the information (Crano & Prislin, 2006; Petty & Cacioppo, 1986). Peripheral processing is more likely to occur if the message is perceived to have little personal relevance, distracting information is present, the viewer is limited in their ability to attend to the message (for instance due to time pressures or low literacy levels) or the viewer prefers not to think deeply (Petty & Cacioppo, 1986). These factors lower the viewer's ability or motivation to attend to the message. Although peripheral processing can enable a viewer to understand and be persuaded by a message, cognitive (and subsequent behaviour) change is likely to be short-lived and susceptible to other influences unless further elaboration on the message occurs (Petty & Cacioppo, 1986). Therefore, health intervention designers should seek to stimulate central processing of intervention messages to increase the likelihood of promoting sustained behaviour change (Robertson, 2008). While the receivers' environments and preferences for thinking deeply are beyond the control of intervention designers, the intervention content can be designed to ensure it is relevant to the receivers, contains strong factual arguments and minimal distracting (non-relevant) information, and is pitched at an appropriate level according to the audience's literacy levels. On the other hand, when targeting audiences who have a low motivation or ability to process messages on the desired health behaviour, including cues for peripheral processing (e.g. using an attractive or trustworthy source) could help to promote temporary attitude change (Petty, Barden & Wheeler, 2009). In such cases Petty and colleagues (2009) suggest first using peripheral processing cues to make a health behaviour temporarily more attractive (i.e. change attitudes), then employing methods to stimulate central processing when the audience is more motivated.

There is extensive empirical research to support the ELM's propositions of central and peripheral processing pathways, and the factors that affect how a message is processed (for reviews see Petty & Cacioppo, 1986, and Petty, Barden & Wheeler, 2009). Much of the early research was in experimental settings often involving undergraduate student samples and commercial advertising messages. However, the ELM has also been applied to health messaging; for example, Jones, Sinclair and Courneya (2003) manipulated the source credibility of information promoting physical activity to young adults. Participants receiving information from a more credible source were found to elaborate more on the message and express more positive exercise intentions and behaviours both immediately after receiving the information and two weeks later. This study also highlights that message factors can play multiple roles; while source credibility can be used as a heuristic cue for peripheral processing when a receiver has low motivation or ability to process the message, for receivers who do have the motivation/ability to engage in central processing a credible source can prompt engagement with a message, leading to elaboration (Jones et al., 2003).

The ELM has advanced message designers' understanding of the factors that influence whether a message will be attended to and how it will be processed; however, it does not predict how message factors will be interpreted by a given audience (Fishbein & Cappella, 2006). For example, what is perceived by an intervention designer as a strong argument for adopting a healthy diet might be seen as a weak or irrelevant argument by the intended audience. This limitation of the ELM emphasises the importance of conducting pilot work with members of the target population, in order to assess their motivations and abilities, and to test intervention messages to gauge how they are received (Fraser, Smith & Bostock, 1997).

2.2.7 Health information format

As highlighted in the ELM and appraisal theory of interest, the way in which health information is presented can affect how an individual will process the information and, in turn, how they will respond to it. Health information has traditionally been communicated in person (e.g. in doctor-patient consultations) or by printed materials (e.g. leaflets, posters). With advancing technology, health information is now conveyed via many more channels, including radio and television programmes, websites and social media. All of these channels can be used to communicate various types of health information; for example, information to raise awareness of health risks, to provide instruction, or to increase understanding of a health issue. Non-personal communications (i.e. those that do not involve a health practitioner or campaigner directly delivering information to the recipient) generally present less resource-intensive and thus less expensive formats (Ammann, Vandelanotte, de Vries & Mummery, 2013; Fraser et al., 1997). Non-personal communications, particularly those delivered via the internet, also have the potential to reach many more people than personal communications (Fitzgibbon et al., 2007). Non-personal communications therefore seem particularly well-suited to interventions aiming to promote physical activity and healthy eating to the large proportion of the public who are overweight and inactive, but who may not otherwise have any health concerns that would necessitate contact with a health professional.

Non-personal communications rely on text, images, animations and audio recordings to convey information. With regards to health promotion interventions, this information needs to meet several aims: generate interest and engage the target audience; meet the audience's informational needs (i.e. address a gap in their current knowledge); influence cognitive determinants of behaviour change; and provide the audience with the skills required to make a behaviour change (Abraham & Kools, 2012). Meeting these aims can be particularly challenging for health behaviour interventions as health issues are often multifaceted, meaning the information to be conveyed can be complex.   The design and presentation of text, images, animations and audio recordings can greatly affect how well the information meets these aims, mainly by influencing the audience's motivation to attend to it and the ease with which it can be understood (Bol et al., 2016; Byrne & Curtis, 2000).

2.2.7.1 Expository texts, graphics and audio communications

Written communication (specifically expository text, i.e. text that is intended to explain or describe something) has proven more persuasive and comprehensible for conveying complex health messages than graphic, audio or audio-visual communications. This was reported several decades ago by Chaiken and Eagly (1976) who found that, for complex ('difficult to understand') health messages, a written medium was both more persuasive and comprehensible than audiotaped or videotaped media. For simple ('easy to understand') messages, however, persuasion was greatest for video, then audio and least for written but comprehension was not affected by communication medium. These findings have been replicated over the years; for example, Furnham, Gunter and Green (1990) showed that complex scientific information was better recalled, in both free and cued recall situations, when the factual material had been presented in print rather than audio or audio-visual (i.e. a 'talking head' video recording). Byrne and Curtis (2000) tested the ability of 17-year-old students to process a complex health message about a fictitious wheat mite found in white bread when conveyed in written or audio-visual formats. The two written conditions (time limited or not) obtained the highest recall scores compared to audio-visual conditions (audio accompanied by either message-relevant or irrelevant images) but there were no significant differences between the two written conditions. This suggests that the superiority of written communication for complex information is not due to people being better able to take in the information at their own pace and re-read information as needed (i.e. self-pacing); if this was the case, participants in the time-limited condition would be expected to have poorer recall. Instead, Byrne and Curtis (2000) suggest that audio-visual presentation can distract attention from the core message, thus diminishing processing power that can be dedicated to the message. In their study, the audio-visual conditions were reported to be more distracting (even when the accompanying images were relevant to the message) than the written conditions.

More recently, Meppelink, van Weert, Haven and Smit (2015) have shown that the effectiveness of different communication formats varies according to the audience's health literacy levels. Health literacy has been defined as the "ability to obtain, process, understand, and communicate about health-related information needed to make informed health decisions" (Berkman, Davis & McCormack, 2010, p. 16). Employing a 2x2 experimental design, Meppelink and colleagues (2015) showed people written and spoken health messages accompanied by either static illustrations or animations. The information was the same for each condition and concerned colorectal cancer; the intent of the information was that audience members would take up regular cancer screening. Accuracy and extent of recall were assessed after viewing the messages, as were attitudes to the messages, screening behaviour and behavioural intent to attend a screening. For those with high health literacy the mode of the messages did not significantly affect accuracy of recall, attitudes or intentions. However, people with low health literacy levels had significantly better recall when the information was spoken alongside the animation – this was the only condition in which their recall was on a par with those in the high health literacy groups. That is, the animation and written information nor the spoken information with static illustrations were effective at improving recall level for those with low healthy literacy; spoken information needed to be combined with animated images. People with low health literacy also reported significantly more positive attitudes towards the spoken messages than the written messages and, for both groups, more positive attitudes predicted greater intentions to attend screening among this group. The authors proposed that the beneficial effect of spoken over written presentation for people with low health literacy may be because the spoken format engages the auditory processing channel, freeing up the audience's visual processing channel to process the animation. This is based on a dual-channel model of information processing, proposing that humans have two limited-capacity channels available (visual and auditory) and that information presented in both modes will be stored better in the memory. However, this was not found to be the case for those with high health literacy, possibly because their processing capacity for each channel was higher and so they were able to process all the information when presented in one mode only.

The positive effect on attitudes of information being conveyed via both spoken word and animation for people with low health literacy, may have been due to this format being easier to process since each processing channel is less loaded (Meppelink et al., 2015). Research has shown that the easier information is to process and comprehend, the more likely an individual is to feel positively about it, find it interesting, continue to attend to it and accept the message (Kahneman, 2011; Song & Schwarz, 2010; Wright, 2012). This is in accordance with the appraisal theory of interest in that a stimulus that is too complex and therefore hard to comprehend will not sustain interest (Silvia, 2008, 2010). However, using animations has not always been found to have positive results. A meta-analysis of experiments comparing static and animated images, found animations to have a medium-sized advantage for instructional learning (Höffler & Leutner, 2007). However, this was only the case for animations that were representative of the message rather than 'decorational' (i.e. images that do not explicitly depict the instructional message to be learned, rather their main function is to motivate the learner when accompanying informational text; Höffler & Leutner, 2007). Further problems with animations come from their transience. As an animation advances, new frames replace old ones and thus the latter are no longer available to the viewer; this places strong demands on memory if the viewer needs to integrate information from prior frames into new frames (Hegarty, 2004). With static images people can, and do, look back to the image and inspect certain elements as often as they want to – the image acts as an external memory aid, which is thought to relieve memory capacity. Further, Hegarty (2004) has reported that people viewing static images that illustrate text information about processes tend to 'mentally animate' the images; in line with the ELM, this mental elaboration can lead to more lasting comprehension. Using interactive animations may provide a means of overcoming some of the problems associated with moving visual displays; however, the interactive element can itself place extra cognitive demand on the viewer. For example, if the interface used for interaction requires significant attention on behalf of the viewer in order to navigate, then processing power will be taken away from understanding the animation's content (Hegarty, 2004).

Static illustrations have long been used to convey health information, both to patients/lay people and health professionals (Scheltema, Reay & Piper, 2018). Although technology has enabled animated and interactive images to be widely accessible, static illustrations continue to be widely used both in printed and online formats and may present a more affordable option for health information providers. Emerging graphics technology allows very realistic images to be created and a key question for health information providers to consider is what type of images are best for educating the target audience. A recent qualitative study assessing attitudes towards illustrations of medical procedures, found that both patients and health professionals preferred more realistic, detailed images and also reported finding these to be more credible (Scheltema et al., 2018). However, this contrasts with a large body of evidence in the fields of health education, education, psychology and marketing showing that simple pictures, with minimal distracting details, are most effective in terms of conveying information comprehensibly (see review by Houts, Doak, Doak & Loscalzo, 2006). This is particularly the case for people with low literacy skills, who are likely to attend to irrelevant details in more complex images (Houts et al., 2006). It therefore seems that a balance needs to be struck between creating images that are liked and seen as trustworthy while also conveying information as intended. These factors will vary according to the needs of the target audience and type of information to be communicated (Williams & Cameron, 2009). Therefore, just as preliminary work is needed to determine what BCTs should be included in a health intervention, preliminary work will also be needed to design and pilot-test health communications (Kools, 2012).

2.2.7.2 Narrative communication

Traditionally, health communication has taken a direct, expository form – explicitly describing, explaining and illustrating health information. Narrative communication, in contrast, takes the form of a story, into which factual information can be embedded. Narratives are emerging as an important tool for promoting health behaviour change (Hinyard & Kreuter, 2007; Thompson & Kreuter, 2014) and have been defined as “any cohesive and coherent story with an identifiable beginning, middle, and end that provides information about scene, characters, and conflict; raises unanswered questions or unresolved conflict; and provides resolution” (Hinyard & Kreuter, 2007, p. 778). This form of communicating has been found to have particular power in expressing complex health information in such a way that enhances viewers’ understanding and leads to persuasion (Niederdeppe, Shapiro, Kim, Bartolo & Porticella, 2014). This is thought to be due to the ability of narratives to ‘transport’ the viewer into the narrative world; beliefs or feelings that the narrative evokes while the reader is in the narrative-world, can be carried over when the reader ‘returns’ to the real-world (Green & Brock, 2000). More (deeper) transportation is associated with more and stronger narrative-consistent beliefs (Green, 2004; Green & Brock, 2000). Evoking vivid imagery and identification with the characters are thought to be the mechanisms by which transportation is achieved (Thompson & Kreuter, 2014).

Accordingly, deeper transportation into a narrative is aided by higher perceived realism of the story and readers' prior knowledge or experience of issues that occur in the narrative (Green, 2004). For example, Frank, Murphy, Chatterjee, Moran & Baezconde-Garbanati (2015) showed women a narrative involving a mother and her two daughters discussing one of the daughter's recent diagnosis of human papilloma virus (HPV) infection and a new vaccine. The narrative aimed to educate women on HPV and ultimately promote uptake of the vaccine. Women who identified more with the characters in the narrative were more likely to perceive the vaccine to be effective and, when asked six months after viewing the narrative, were more likely to report that they had consulted a health professional about the vaccine.

Slater and Rouner (2002) proposed that greater transportation and identification with characters reduces the ability of the viewer to critically review (or elaborate) the arguments in the narrative; this would reduce counter-arguing and, Slater and Rouner suggest, lead to increased persuasion. In relation to the ELM, this would suggest that narratives are processed via a peripheral route, leading to short-term persuasion. However, this does not seem to be the case as many researchers have reported persuasive effects to increase over time (Appel & Richter, 2007; Shen, Sheer & Li, 2015). The increases in narrative-consistent beliefs over time are known as sleeper effects and are thought to occur as the narrative's message is integrated with an individual's existing knowledge and their awareness that the narrative is a story diminishes (Appel & Richter, 2007). In line with this and in contrast to Slater and Rouner, Cohen (Cohen, 2001) proposed that narrative transportation actually leads to greater elaboration since the viewer puts him/herself in the place of the character and thinks about how they would think and feel. Recent findings by Igartua and Vega Casanova (2016) lend support to this proposition, showing that greater identification with a character in an audio-visual narrative led to greater elaboration, which in turn was associated with greater persuasion regarding sexual-health behaviours. Thompson and Kreuter (2014) further posit that by helping people view an issue from another perspective (i.e. that of the narrative character), narratives can also reduce the likelihood of negative reactance or counter-arguing that standard expository messages can provoke and which decrease the likelihood of a message effecting positive attitude and behaviour change.

A recent meta-analysis investigated the persuasive effects of narratives in health communication (Shen et al., 2015). Overall, narratives were found to produce small but significant persuasive effects ($r = .06$, $p < .01$), which is similar in magnitude to other effective health communication techniques such as tailoring messages to the viewer (Noar, Benac & Harris, 2007). However, the impact of narratives was moderated by length (for text narratives) and type of behaviour change being promoted, with longer texts (>400 words) and those promoting uptake of positive health behaviours (rather than cessation of negative behaviours) being significantly more likely to promote attitude, intention and behaviour change (Shen et al., 2015). The authors caution that given the rapid pace of technological development, more research is needed to better understand the conditions under which narratives are most and least effective. For example, increasingly text-based communication is delivered online rather than in print and this may affect how people engage with the messages.

2.2.8 Concluding remarks to section 2.2

Changing people's behaviour will be vital for preventing a continued rise in the non-communicable disorders that have become common in today's society. Developing interventions to help promote health behaviour change is therefore a public health priority, yet designing effective interventions has proven difficult. Best practice guidance now exists to help intervention designers in their task and a growing body of evidence highlights the most effective techniques to use for promoting different behaviours. Consideration also needs to be paid to the communication of the intervention content – this has received relatively little attention in behavioural science research yet is crucial for ensuring audiences engage with an intervention. Combining theories and evidence from the health communication and behavioural science fields should help to create interventions that effectively promote the behaviour change that is so urgently needed for our populations' health.

2.3 Using the evolutionary mismatch concept to support health behaviour change

The first section of this chapter reviewed the evidence on the concept of an evolutionary mismatch –the idea that human cultural evolution has occurred too rapidly for our genetic evolution to keep up, and so humans are poorly adapted to cope with the modern developed environment, predisposing us to chronic disease. It was concluded that there is strong support for this concept and that it can provide context for understanding both our current behaviours in developed society and the physiology that makes us susceptible to chronic disease. The research presented in this thesis explores using the mismatch concept in a health promotion intervention to help people make healthy changes to their diets and increase their physical activity. In light of the literature reviewed in the second section of this chapter, the research in this thesis takes a systematic approach to developing the intervention, conducting formative qualitative and quantitative work before piloting a comprehensive intervention. SDT and the TPB are applied both to inform the intervention content and to help interpret the findings from empirical work. Evidence from the fields of behavioural science and communication is drawn on in an attempt to make the intervention engaging and effective at helping people make behaviour changes.

The evolutionary mismatch concept will primarily be used to frame health information on the importance of physical activity and nutritious diets for health. By highlighting how rapidly human culture has evolved and the ways in which our bodies are adapted to ancestral diets and physical activity levels, it is hoped that the mismatch frame will provide a meaningful rationale for increasing activity and making dietary changes. It will also provide a platform for introducing physiological information, e.g. on how chronic diseases develop as our bodies interact with our high income, developed environment. Standard health promotion information does not provide this depth of detail and it is hoped that this physiological information will lead to a greater level of understanding and boost intentions to change behaviour. To be clear, the intervention will not be advocating a return to ancestral lifestyles; indeed, specific diets and levels of activity will not be prescribed nor will a set amount of weight loss. Rather, people will be encouraged to make small, sustainable changes in a positive direction for their health. This approach is based on the recognition that there is no 'one size fits all' diet or activity level that will be achievable, ensure a healthy weight is maintained and prevent communicable chronic disease for everyone (Blair, LaMonte & Nichaman, 2004; Public Health England, 2016a; Thompson et al., 2009). The level of activity and dietary intake needed to maintain a healthy mass and prevent disease for any individual is partly determined by unmodifiable genetic factors (Blair et al., 2004). Feasibility and acceptability of an activity or dietary regime will also vary individually yet are crucial for adherence (Sekhon, Cartwright & Francis, 2017; Teixeira, Patrick & Mata, 2011). However, it is widely accepted that, for physical activity, any is better than none and, although guidelines recommend at least 150 minutes of moderate intensity physical activity each week (for adults), more activity will bring greater health benefits (Blair et al., 2004; Public Health England, 2016b). In terms of caloric intake, although the standard recommendations are 2000kcals/day for women and 2500kcals/day for men (Public Health England, 2016a), these come with the caveat that an individual's required intake will depend on their activity levels and current body mass. With regard to types of food, recommendations are in terms of food groups (e.g. fruit and vegetables, dairy) and the advice is for more of certain groups and less of others, rather than specific amounts of individual foods. Furthermore, there is evidence that even modest weight loss (5% of initial body mass) can lead to significant improvements in risk factors for T2DM and CVD, regardless of BMI status (Wing et al., 2011). Therefore, the present work will seek to promote increases in physical activity and improvements in diet that individuals feel are feasible and meaningful to them, rather than imposing specific targets that an individual may not feel are achievable or worthwhile. Allowing people to choose what changes to make that are feasible and meaningful to them should promote a greater sense of autonomy and long-term maintenance of healthier behaviour (Sekhon et al., 2017; Teixeira et al., 2011), which ultimately is the goal for health interventions.

CHAPTER 3. Study 1: Exploring the potential of the evolutionary mismatch concept

3.1 Introduction

The rising prevalence of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) in the UK has been largely attributed to widespread poor diet and physical inactivity, and governments have highlighted the urgent need to tackle this by promoting healthy behaviour change (HM Government, 2008, 2010; Scarborough et al., 2011). Government policy emphasises that providing the public with good quality, accurate information about health is an important first-line of intervention for promoting health and encouraging people to take an active role in their healthcare (HM Government, 2010; Protheroe et al., 2015). Within the field of behavioural science, imparting knowledge and understanding is recognised as a valuable behaviour change technique (BCT) for its ability to improve psychological capability (to engage in a desired behaviour) and reflective motivation (achieved through reasoned, conscious thoughts rather than habitual processes) (Michie, van Stralen, et al., 2011).

Public health promotion campaigns, aiming to inform the general public about diet and physical activity (PA) in order to encourage healthy behaviour change, have historically focused on providing single, simple messages, ostensibly to improve the likelihood that the messages will be understood and remembered (Cavill & Bauman, 2004; Piggin & Lee, 2011). However, in striving for simplicity, these wide-reaching interventions fail to explain why or how PA and diet impact on health. Population surveys have indicated that the public are poorly informed about why PA and diet are important for health and how to act in order to meet recommendations for a healthy lifestyle (Knox et al., 2013; Parmenter, Waller & Wardle, 2000). A deeper understanding of why PA and diet are important and how they can help prevent T2DM and CVD might help people to see the need for behaviour change and also enable them to make better lifestyle choices. The present study formed the first part of a research programme aiming to design a behaviour change intervention that promotes a deeper understanding of PA, diet and how they impact on health, and thus support healthy behaviour change. This research is specifically targeting adults who are at higher risk of developing T2DM and CVD and need to make changes to their diet and activity levels.

An inherent challenge in promoting a deeper understanding of health is that information will need to be conveyed to audiences who are confronted every day with competing messages from various sources, including the popular press (Cavill & Bauman, 2004; Wilson, 2007).

Therefore, there is a need to find ways of providing information that are attention grabbing, interesting and easy to comprehend while still sufficiently detailed. The present study proposes that using an evolutionary mismatch frame might help in providing more detailed information about diet and PA, and thus promote a deeper-level of understanding. The evolutionary mismatch concept holds that genetic evolution has failed to keep pace with rapid changes that have occurred recently in the human cultural environment (particularly, in affluent, developed society) and that the resulting mismatch between our genes and environment is leading to chronic disease (Chakravarthy & Booth, 2004; Konner & Eaton, 2010; Leonard, 2008; Lieberman, 2013). The mismatch concept is particularly apt for illustrating concepts related to diet and PA, since cultural changes over the last 50 years, in particular, have led to a near reversal of these two factors. That is, for most of human evolutionary history, PA was a necessary and regular part of daily life and diets predominantly comprised low energy density foods; in contrast, in modern developed society, technology has engineered PA out of daily life and energy dense food is cheap and readily available (Leonard 2008; 2010). The ancestral environments adapted the human genome in ways to optimise energy efficiency, for example by an enhanced capacity to store excess energy as fat tissue (Leonard, 2008; Lieberman, 2013), but in the modern environment these adaptations heighten our risk of developing T2DM and CVD.

The concept of an evolutionary mismatch might be particularly helpful in providing health information for a number of reasons. Firstly, it provides an over-arching framework for introducing information on human evolution, physiology and behaviour, thus enabling more in-depth information to be delivered in a cohesive manner. Secondly, the mismatch concept can help explain not only *what* lifestyle factors cause disease but also *why* these factors cause disease, thus giving a stronger rationale for the need to adopt healthy behaviours. It can also provide a guide for people to use in working out what behaviour changes they need to make (e.g. when faced with a choice of foods it might be helpful to consider which is closest to the foods available to our ancestors – i.e. contain the least refined sugar, fat and salt, all of which are known to heighten the risk of chronic disease; Katz, 2005). An ancestral guide also emphasises that PA and a healthy diet need to be part of everyday life, thus changes to behaviour need to be maintained and not seen as short-term, quick fixes to improve health. Recently, the need for interventions to promote maintenance of healthy behaviours has been highlighted in the field of weight loss, where it is now clear that many interventions have only been successful in promoting short-term behaviour change and so initial body mass reduction is followed by regain (Sniehotta, Simpson, et al., 2014).

Using the evolutionary mismatch concept to deliver health-related information would be novel, in that most health promotion messages do not discuss evolution. This could provide a further advantage to using the mismatch concept since novelty of format or content is known to be an important factor in gaining people's attention and generating interest in health-related information (Crutzen & Ruiter, 2015; Louis & Sutton, 1991; Silvia, 2008). However, it is also important that new information is believable in order to be accepted and acted upon (Cappella, 2006). Many of the cultural changes, leading to a reduction in PA and change in diet have occurred in the last 50 years (Lieberman, 2013; Ng & Popkin, 2012); this means that adults receiving an evolutionary mismatch-based health message might be able to reflect on the changes that they have lived through, which could enhance the believability of the information.

While the mismatch concept could be a useful way of framing detailed information on diet, PA and health, the way in which this information is communicated will also impact on its ability to effect changes in understanding. Many methods of communicating health information exist, from mass media campaigns to face-to-face health professional-patient consultations. The present study used printed resources (text and graphics) due to the need to convey an amount and complexity of information that is more than could be included in a mass media campaign or typical consultation with a health professional. Written communication (specifically, expository text), as opposed to graphics alone, audio or audio-visual communications, has proven more comprehensible for conveying complex health messages (Byrne & Curtis, 2000; Chaiken & Eagly, 1976). However, graphics can be used to make printed materials more appealing, thus encourage people to attend to the information, and to support text by emphasising a point or visually depicting a complex concept (Houts et al., 2006; Wright, 2012). Furthermore, there is extensive evidence from the fields of education, psychology and health that presenting (relevant) pictures in addition to text information significantly enhances recall – this is known as the pictorial superiority effect (Houts et al., 2006).

Several cognitive processes need to occur in order for a message to affect an individual's decision making (Cappella, 2006; McGuire, 1999): attention, comprehension, cognitive elaboration (generating thoughts about the message), acceptance (agreement with the message) and storage in memory. In designing health information resources, therefore, consideration needs to go to ways of enhancing the likelihood of these processes happening. The novelty and complexity of resources have been proposed as the two key determinants for attracting attention, which is an important first step in generating interest (Crutzen & Ruiter, 2015; Silvia, 2008). Novelty has a simple positive relationship with attention: the more novel a resource looks at first sight the more likely it is to grab attention (Crutzen & Ruiter, 2015). Resource complexity, however, has an inverted u-shaped relationship with attention: if something is perceived to be too complex, then it can immediately be deemed beyond a person's ability to process and so no further attention is paid. Yet if the resource is so simple that the message is immediately obvious, then no further attention is deemed necessary (Crutzen & Ruiter, 2015).

With regards to comprehension and acceptance, research has suggested that the easier a resource is to read and comprehend the more likely an individual is to feel positively about the resource, which in turn improves the chances of them finding it interesting, continuing to read it and accepting the message (Kahneman, 2011; Meppelink et al., 2015; Silvia, 2008; Song & Schwarz, 2010; Wright, 2012). However, messages that are too easy to process tend not to stimulate cognitive elaboration, rather they prompt simple acceptance (Kahneman, 2011; Petty & Cacioppo, 1986). Cognitive elaboration, or deeper level thinking, leads to better storage in memory and sustained attitude change (Petty & Cacioppo, 1986). Although materials that are harder to read can encourage cognitive elaboration, in unconstrained conditions (i.e. where there are no other factors, such as time constraints, that would limit the amount of attention an individual could devote to the material) an individual will be unlikely to maintain attention on a resource that is hard to process. Therefore, other means need to be employed to encourage elaboration while still ensuring a resource is easy to process. Petty and Cacioppo's (1986) elaboration likelihood model of information processing purports that when the perceived personal relevance of a message is high, more cognitive elaboration will be provoked. A key goal in designing health communications, therefore, is to ensure that they are perceived as personally relevant (Petty & Cacioppo, 1986; Wilson, 2007). However, cognitive elaboration also needs to be at the right valence (i.e. positive and consistent with the message) in order for a message to have the desired effect (Byrne & Niederdeppe, 2011; Niederdeppe et al., 2014; Petty & Cacioppo, 1986). If a message is misunderstood this can lead to elaboration in an unintended direction, potentially promoting unintended actions (Byrne & Niederdeppe, 2011). For example, a health promotion poster depicting both healthy and unhealthy foods could prime, or bring to an individual's awareness, thoughts of an unhealthy food, which might prompt them to seek out that food (*"Oh, I had forgotten how much I like chocolate digestives!"*). Counter-arguing (reactance) to a message is another example of negative valence elaboration and will preclude acceptance (Byrne & Niederdeppe, 2011). Counter-arguing involves thinking or stating arguments that explicitly refute the intended message (Niederdeppe et al., 2014). For example, on hearing a message that running is a good and accessible way for people to improve their health, an individual may respond that the injury risk from running is very high and so running is actually bad for one's health.

The use of narratives in health communication is one method that has proven useful in reducing counter-arguing (Niederdeppe et al., 2014). Narrative messages convey health information through telling a story about a particular character. Their ability to reduce counter-arguing is thought to be due to their ability to emotionally engage and 'transport' the reader into a narrative world, through evoking vivid imagery and identification with the characters in the story (Frank et al., 2015; Green & Brock, 2000; Thompson & Kreuter, 2014). Beliefs or feelings that the narrative evokes while the reader is in the narrative-world, can be carried over when the reader 'returns' to the real-world. More (deeper) transportation is associated with more and stronger narrative-consistent beliefs (Green, 2004; Green & Brock, 2000). Cappella (2006) posits that narratives, through their power to emotionally engage people, also have a greater ability to sustain the attention of low-motivation audiences. In addition, narratives present an opportunity to model desired behaviours via the character(s) in the story (Frank et al., 2015). Modelling behaviours has proven to be an effective behaviour change technique that acts to improve perceived self-efficacy (Abraham, 2012b; Abraham & Michie, 2008; Michie, Ashford, et al., 2011).

The present study employed graphics, expository text and narratives as means of conveying information about diet, PA and their impact on health, in an evolutionary frame. Two forms of graphics were designed: graphics to primarily attract attention and stimulate interest in the more informational resources; and graphics primarily aimed at improving understanding of concepts covered in the expository texts. Expository texts were written using the active voice, in an attempt to make them more engaging (Parrott, 1995) and everyday language was used (except where scientific terms were necessary) in order to enhance the 'readability' (NIACE, 2009). Narratives were composed to illustrate how individuals could apply the information from the expository texts in their own lives.

In developing health interventions it is important to engage with potential members of the target user group (Abraham, 2012a; National Institute for Health and Clinical Excellence, 2007). This can form part of a needs assessment (also termed elicitation research) whereby salient beliefs, attitudes, feelings of self-efficacy and motivations relevant to the target behaviours can be identified. Needs assessment is an essential first stage in intervention design since it can highlight potential cognitive determinants of behaviour change that designers can then target with various behaviour change techniques in the intervention (Abraham, 2012a; Michie et al., 2014). This in turn enables designers to identify appropriate theories of behaviour change that incorporate the potential causal determinants. Use of theory in behaviour change intervention design has increasingly been acknowledged as important since this promotes a systematic approach to selecting appropriate behaviour change techniques to apply and mediators to assess in evaluating intervention effectiveness (Craig et al., 2006; Glanz & Rimer, 2005; Michie et al., 2014; Michie et al., 2013; Michie, van Stralen, et al., 2011). Furthermore, there is some evidence that theory-based interventions to promote PA and healthy dietary behaviours are more effective than those that were not theoretically informed (Ammerman et al., 2002; Greaves et al., 2011; Taylor et al., 2012). With regards to designing informational resources to use in interventions, engaging with potential members of the target user group to 'pre-test' early drafts helps ensure that the resources are attractive, understandable, engaging, acceptable and perceived as personally relevant (i.e. that they are likely to positively influence the cognitive processes needed to occur to affect an individual's decision making) (Fitzgibbon et al., 2007; Fraser et al., 1997; Houts et al., 2006; Wright, 2012). Given the novelty both of using the evolutionary mismatch concept and providing detailed information in relation to diet and PA, engaging with members of the target user group would be particularly beneficial in order to identify potential barriers and facilitators to this approach.

This was an exploratory study, involving a sample of adults who were not highly physically active or lean (i.e., mirroring the final target group), to help guide the further development of an intervention to promote a deeper understanding of PA, diet and how they impact on health, and thus support healthy behaviour change. The study aimed to explore the potential of using the evolutionary mismatch concept as a frame for delivering information in order to impart a deeper understanding of PA, diet and how they relate to health. The potential of the concept was evaluated in terms of acceptability and ability to engage participants. A second aim was to explore the relative potential of a set of evolutionary mismatch-based informational resources (graphics, expository texts and narratives) to bring about intended proximal outcomes (generate interest, be easy to understand, be perceived as personally relevant and be memorable).

3.2 Method

3.2.1 Design

A mixed-method design was followed, using semi-structured interviews and two short questionnaires. Qualitative semi-structured interviews were chosen for this exploratory research since they provide an opportunity to gain detailed insights into a broad range of potentially important factors concerning participants' interpretations and responses to the resources (Smith, 2008; Yeo et al., 2014). A one-to-one interview format was chosen, in which participants were shown the resources and discussed each in turn with the interviewer, as this most closely matched the situation in which the resources were intended to be used, i.e. an individual setting where the person reads or views the materials in their own time. Questionnaires were used in addition to the interviews and served several purposes: the first questionnaire, delivered immediately after the interview, collected demographic details and ordinal data regarding participants' opinions of the graphics they were shown. The second questionnaire, delivered one week after the interview, aimed to ascertain if and what participants had thought about the information in the resources in the intervening week. The more structured, quantitative questionnaire data were not intended to validate the qualitative findings, rather the different methods were used to provide a fuller picture of participants' experience of the resources (Ritchie & Ormston, 2014; Shenton, 2004).

The study received ethical approval from the Research Ethics Approval Committee for Health (REACH) at the University of Bath on 27th February 2015 (ref. EP 14/15 112).

3.2.2 Participants and recruitment

A purposive sampling approach (Braun & Clarke, 2013) was taken, aiming to hear from adults who could benefit from being more active or making changes to their diet and thus might benefit from the resources. Adults aged 35 to 74 years who did not have a mobility-limiting condition and did not report themselves to be both highly active and lean were sought for the study. Thirty-five was taken as the lower age cut-off since the prevalence of both obesity (a strong risk factor for T2DM and CVD) and T2DM sharply increases for men between the 16-34 age group and the 35-54 age group (Bridges et al., 2013; Diabetes UK, 2012). For women, prevalence also increases after 34 although less sharply. 'Highly active' was defined as engaging in activity (leisure or work) that makes you out of breath, break into a sweat and find it hard to talk for at least one hour on most days of the week (FAO, 2001). 'Lean' was defined as having a BMI of less than 25 and a waist circumference of less than 84cm (34in) for men or 76cm (30in) for women; these cut-off points were based on the mean waist circumference values of people in the 'normal' BMI category of the Third National Health and Nutrition Examination Survey (Janssen, Katzmarzyk & Ross, 2002). Participants also needed to be sufficiently fluent in English to be able to participate in recorded interviews and compose responses to open-ended questionnaire items.

A target sample size was set at 20. This size was deemed appropriate to balance the need to attain a range of views, in order to be more representative of the heterogeneous target population, with the acknowledgement that qualitative interviews yield detail-rich data that requires large amounts of time to analyse (Ritchie, Lewis, Elam, Tennant & Rahim, 2014). Braun and Clarke (2013) have advised that between 10 and 20 individual interviews provides a suitable amount of data for a medium sized project, or study within a larger project, using thematic analysis. A similar qualitative interview study to aid the development of informational health resources (Cueva, Dignan, Lanier & Kuhnley, 2014) found that data saturation (i.e. when no new themes arise with new participant data) was reached with 20 participants.

Advertisements for the study were placed in the local media and around the University. All advertisements stated brief details of what participation would involve, the type of participants sought (i.e. eligibility criteria), that £20 Amazon vouchers was offered as an incentive and details of how to contact the researcher for more information or to volunteer to take part. It was also made clear that participation would be confidential. These recruitment methods preclude the ability to calculate response rates, since it cannot be determined how many people saw the advertisements.

On receiving an enquiry about participating in the study, the researcher answered any direct questions and sent the individual an information sheet. At this point, the researcher also checked that the individual met the eligibility criteria, based on their self-reported information. If the person was eligible and willing to take part, a convenient time for their interview was set.

3.2.3 Materials

3.2.3.1 Evolutionary mismatch-based resources

Graphics to generate initial interest (Mismatch concept graphics)

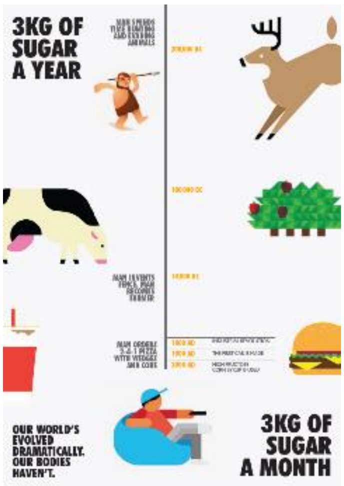
Professional graphic designers, Mytton Williams, were employed to help develop graphic resources. The research team met with the designers and provided a detailed brief of the project and what graphics were intended to convey. The designers then developed several possible initial resources, some of which were selected and developed further through an iterative process, involving close communication between the researcher and designers. The resulting four styles of graphic were designed to generate initial interest in the resources (‘Timeline’, ‘Half Faces’, ‘Lists’ and ‘Future Figures’; Figure 3.1a-d). They sought to convey the main mismatch concept (i.e. that the human environment has evolved too rapidly in recent years for natural selection of the body's genes to keep up, and the resulting mismatch poses a risk to health) in an eye-catching, quickly understandable way.

Graphics to illustrate specific physical activity and diet concepts

Eight graphics were designed as potential means of illustrating different points, relating to PA and diet from an evolutionary perspective, that were covered in the expository texts. The graphics are included in Appendix 3.1 (a-h). These graphics were not professionally designed but were used to gain an idea of styles of illustrative graphic that were understandable and engaging to participants and thus could be developed further by graphic designers in future iterations.

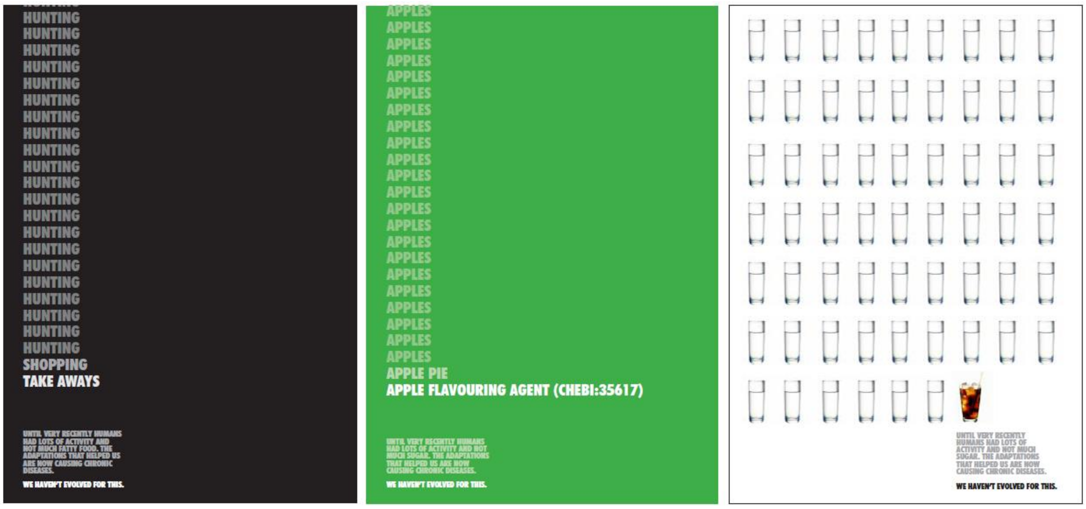
Figure 3.1 Mismatch concept graphics (a – d)

a. Timeline

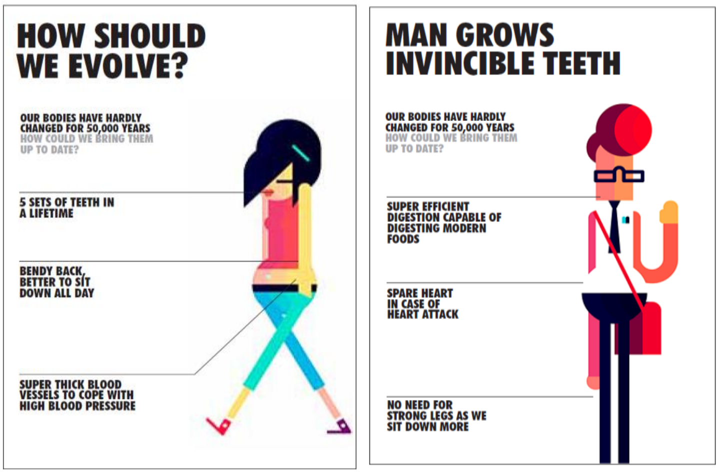


b. Half Faces ('Running' and 'Sugar')

c. Lists ('Hunting', 'Apples' and 'Drinks')



d. Future Figures ('How should we evolve' and 'Invincible teeth')



N.B. For styles b-d, all graphics within each style were presented at once.

Expository texts

Three expository texts were written based on a wide body of literature from the fields of evolution and health (key texts include: Eaton and Eaton, 2003; Lieberman, 2013; Lieberman, 2006; Eaton and Konner, 1985; Konner and Eaton, 2010; Booth et al, 2002; Power and Schulkin, 2009; Guyenet and Schwartz, 2012; Keskitalo et al., 2013; Drewnowski et al, 2012). The first text introduced the mismatch concept and gave a brief overview of human evolution and cultural changes (Appendix 3.2); another text covered PA in relation to the mismatch concept, particularly highlighting changes in types and amount of activity through history and focusing on the roles of muscle and fat in glucose metabolism (Appendix 3.3); and a further text discussed diet in relation to the mismatch concept, with a focus on evolved taste preferences, fat storage and how leptin affects weight loss attempts (Appendix 3.4). The texts were checked for accuracy, readability and inclusion of theory-based communication techniques by experts in physiology and health psychology. Initial drafts of the texts were shown to 17 members of the Department for Health's patient and public involvement group (PPI), which consists of members of the public who are willing to be involved in developing and/or participating in health research studies. The PPI group is mostly made up of retired or non-working adults and reflects the typical local demographic for Bath, the majority being white and middle class. Members of the group were sent the texts to read prior to attending a meeting at the University, where they discussed their feedback. The group highlighted that there was a need to emphasise the personal relevance of the content to the reader in order to make it more engaging. The resources were therefore adapted to include more references to modern life. As a result of the feedback it was also decided to include narrative texts to further promote engagement and perceived relevance.

Narratives

Two narratives were composed: one about a male character (John, Appendix 3.5) who had been told by his doctor that he was at high risk of developing T2DM and so was looking to increase his activity levels; and one about a female character (Cathy, Appendix 3.6) who had also received a high risk of T2DM diagnosis and so wanted to make improvements to her diet. The narratives were fictional but the characters and the problems they related were based on commonly cited reasons for not adopting healthier behaviours and popular beliefs regarding PA and diet, obtained from the literature (Fitzgibbon et al., 2007; King et al., 1992; Roberts & Marvin, 2011; Vähäsarja et al., 2015).

3.2.3.2 Interview schedule

The interview schedule (Appendix 3.7) was designed to elicit participants' initial perceptions of the resources and the further thoughts they provoked. The first sections contained questions directly related to the resources and the final section sought general comments on the use of the evolutionary mismatch concept in a health promotion context. Questions were refined with input from two academics with experience of intervention design. Pilot tests with three people also helped refine the questions.

3.2.3.3 Questionnaires

In Questionnaire 1 (Appendix 3.8) participants were asked to rate each of the four main concept graphics for the following five factors: attractiveness, degree to which it grabbed their attention, ease of understanding, interest generated and personal relevance. Ratings were made on 5-point Likert scales from 'not at all' to 'very'. Questionnaire 1 also included a demographic form. This questionnaire was to aid the choice of graphic style to be used in further work with graphic designers, if the evolutionary mismatch concept was found to be useful.

Questionnaire 2 (Appendix 3.9) used a mixture of closed- and open-ended questions to ascertain whether participants had thought further about the resources in the intervening week and, if so, the content of their reflections. This questionnaire was delivered online via Bristol Online Surveys.

3.2.4 Procedure

Data collection took place between March and June 2015. Interviews were conducted in a private office at the University; the participant and researcher sat opposite each other with a small table in between on which the resources were placed when being discussed. The researcher conducting the interviews was the current author, a female postgraduate researcher who had experience of conducting one-to-one interviews. The researcher arranged to meet participants in public locations on the University campus, a couple of minutes' walk away from the office. This enabled her to start building a rapport with the participants (Yeo et al., 2014) while walking to the office and also to elicit some background information, such as why the participant was interested in the study and details about their current lifestyle. This information was recorded in field notes taken while participants were reading the text resources.

Before interviews commenced, the researcher gave a brief overview of the purpose of the study and the structure of the interview. In an effort to gain true reflections of participants' perceptions and thus promote credibility (Shenton, 2004), it was explicitly stated that there were no right or wrong answers and that it was simply participants' honest opinions that were sought. The fact that the researcher had written/designed the resources was not made known to participants and all questions were neutrally framed in order to gain both positive and negative responses. Participants were again assured that the information they provided would be kept confidentially and that participation was voluntary. The researcher then asked participants if they had any questions about the study or procedure; questions were answered and then written consent was taken. Interviews were recorded using an Olympus VN-732PC digital recorder.

All participants were first shown the four styles of mismatch concept graphics; the order in which these were presented was rotated such that the first style (Fig. 1a) was shown first to the 1^{st}, 5^{th}, 9^{th} etc. participants, the next style (Fig. 1b) was shown first to the 2^{nd}, 6^{th}, 10^{th} etc. participants and so on. This procedure was followed so that each graphic style had the opportunity to be presented as entirely novel, which is the context in which they were designed to be used. Questions were asked about a graphic before presenting the next graphic. Following the mismatch graphics, participants then read the introductory text; they were given as much time as they needed to do this and the researcher waited until the participant reported they had finished before asking questions related to the text. After the introductory text, participants were shown either the PA- or the diet-related graphics, informational text and narrative. Participants were randomised into the two conditions (PA and diet) prior to the interviews. Having two conditions was deemed necessary as pilot testing had revealed that showing participants all the resources (i.e. including both PA and diet resources) would make the interviews very long (potentially over three hours). When the interview ended, participants were given Questionnaire 1 to complete. One week after the interview, individual email links to Questionnaire 2 were emailed to participants. On completion of the second questionnaire, participants were sent the Amazon voucher incentive.

3.2.5 Analysis

Interview recordings were transcribed verbatim in Microsoft Word. Transcripts were uploaded to NVivo (Version 10, QSR, Southport, UK) for coding and data organisation. A two-pronged approach was taken to analysis of the qualitative data, employing both a deductive Framework approach and an inductive thematic analysis. A Framework approach is a form of thematic analysis that uses *a priori* codes to organize qualitative data in a matrix (or table) and thereby facilitate both cross-case and within-case analysis (Spencer, Ritchie, O'Connor, Morrell &

Ormston, 2014; Spencer, Ritchie, Ormston, O'Connor & Barnard, 2014). It was applied in the present study to quickly identify the semantic-level elements of the resources (e.g. use of a particular colour or phrase) that influenced their ability to communicate information (as identified from the literature, e.g. interest, personal relevance etc.). This approach was primarily intended to aid quick identification of design factors that would help the further development of resources. Framework matrices (Spencer, Ritchie, O'Connor, et al., 2014) were created in Microsoft Excel for each resource with columns for various communication processes and separate rows for each participant. Cells were completed giving summarised data for the participant relating to the particular column heading. Summaries were kept at a descriptive rather than interpretative level, incorporating direct quotes, in order to stay close to the data (Spencer, Ritchie, O'Connor, et al., 2014).

A more in-depth thematic analysis (Braun & Clarke, 2006, 2013) was conducted in parallel to identify the more discursive and unexpected themes that would provide a picture of how the participants understood and responded to the resources. The researcher initially read through the transcripts and listened to the audio recordings in order to become familiar with the data. For each participant, the Framework matrices were completed first then the transcript was coded as part of the thematic analysis; this enabled further familiarisation with the data before coding. An inductive approach to the thematic analysis was taken (Pope, Ziebland & Mays, 2000), identifying and labelling (i.e. coding) all elements of the transcript that were thought to potentially be relevant to the broad research aim. Codes were then reviewed and condensed if necessary before being organised into themes and sub-themes. Finally, transcripts were reviewed to check that the themes made sense and were supported by the data. To help ensure dependability and confirmability of the study (Meyrick, 2006; Shenton, 2004), throughout the analysis, the researcher discussed the codes and emerging themes with another, experienced researcher. The final themes and their organisation were discussed among the research team.

Questionnaire data were entered into IBM SPSS statistics 22 software for analysis. Frequencies were calculated for Likert scale responses. Qualitative data from open-ended items in Questionnaire 2 were added to the thematic analysis in NVivo and coded after all interview transcripts had been coded. Sources of information (data from the interviews and questionnaires plus field notes taken by the researcher during the interviews) were triangulated to increase the trustworthiness of the interpretations (Hassandra, Goudas & Chroni, 2003; Shenton, 2004).

3.3 Results

3.3.1 Sample demographics and description

A total of 31 people expressed an interest in participating, of whom four were ineligible due either to their age (N=2) or because they were both highly active and lean (N=2). A further seven people did not respond either to being asked for information regarding their eligibility (N=3) or after being sent the information sheet (N=4). Two people had to cancel their interviews due to illness (N=1) or work commitments (N=1). In total, therefore, there were 18 participants (56% female), all of whom completed both the interview and the questionnaires. Interviews lasted between 1 hour 5 minutes and 2 hours 10 minutes (mean length = 1 hour 40 minutes). All except one participant completed Questionnaire 2 within 24 hours of it being sent. The remaining participant completed the questionnaire after a further week, due to personal commitments. Demographic data for participants, according to study condition (PA or diet), are given in Table 3.1. The mean (SD) age for participants in the PA condition was 54.0 (±12.4) years and in the diet condition was 47.7 (±11.6) years. The majority of participants (67% overall and within each condition) were in the overweight or obese BMI categories. Most participants were married (78%), white (95%) and currently working (78%). A large proportion of the sample (83%) had been educated to degree level or higher.

Table 3.1 Demographic characteristics of participants, according to study condition and in total

	PA (N = 9)	Diet (N = 9)	Total (N = 18)
Gender			
Male	4	4	8
Female	5	5	10
Age			
35-44	2	5	7
45-54	3	1	4
55-64	2	2	4
65-74	2	1	3
Height* (m)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)
Body mass* (kg)	78.7 (17.1)	81.1 (11.3)	79.8 (14.1)
BMI* (kg/m^2)	27.5 (3.6)	27.0 (4.1)	27.3 (3.8)
Waist circumference* (cm)	87 (12)	92 (6)	89 (10)
Marital status			
Single	0	1	1
In a stable relationship (unmarried)	1	0	1
Married/civil partnership	7	7	14
Divorced/separated	1	0	1
Widow/widower	0	1	1
Ethnicity			
White	9	8	17
Black/Black British	0	1	1
Employment status			
Employed	4	7	11
Self-employed	1	1	2
Retired	4	1	5
Highest educational qualification			
GCSE or equivalent	1	0	1
A level/NVQ level 3 or equivalent	1	1	2
Bachelor's degree	3	4	7
Master's/postgraduate qualification	3	3	6
Doctorate/advanced professional qualification	1	1	2
Knowledge of evolution prior to interview**	4	6	10
No higher than average UK adult	5	3	8
Higher than average UK adult			
Reason:	3	2	5
General reading/TV documentaries	2	1	3
Topic covered in degree			

*Reported as mean (standard deviation)
**Self-report
PA = physical activity

Brief descriptions of each participant are given in Table 3.2. Three participants had T2DM, two of whom had been diagnosed over 10 years previously, one had been diagnosed within the last 18 months. The majority of participants were interested in making healthy lifestyle changes.

Table 3.2 Brief descriptive details of participants

Partici-pant	Condi-tion	Age	Gen-der	BMI	Employ-ment	Educa-tion	Notes
SK	Diet	37	F	34	FT - office	PG	Interested in nutrition, aware she is not active, wants to lose weight
MS	Diet	53	M	24	PT - office	PG	Considers himself fairly healthy and not looking to change
JG	Diet	38	F	26	PT - office	UG	Worried about own sugar consumption, aware she is not active, wants to lose weight
LS	Diet	43	F	31	PT - office	UG	Interested in food ethics and nutrition, aware she is not active, wants to lose weight
RA	Diet	35	F	27	PT - office	UG	Has chronic fatigue syndrome but looking to increase activity, calorie conscious
FB	Diet	58	M	26	FT - office	PG	Diagnosed with T2DM, considers his diet healthy, and recently started to exercise more
RV	Diet	65	F	22	Retired	NVQ	Has cancer and many dietary restrictions, considers his lifestyle healthy
TS	Diet	61	M	31	PT - office	PG	Recently diagnosed with T2DM, has tried making small changes to diet/PA but aware he needs to do more
LL	Diet	39	F	22	PT - office	UG	Interested in nutrition, considers her diet healthy except for treats, aware she is not active, wants to lose weight
DJ	PA	46	M	28	FT - office	PG	Aware he is not active and would like to become more healthy but not actively looking to change
PW	PA	61	F	31	Retired	UG	Interested in nutrition, considers her diet healthy and happy with current PA but wants to lose weight
PL	PA	61	F	27	Retired	PG	Interested in nutrition, tries to be active by walking, has always wanted to lose weight and tried many diets
SL	PA	51	F	24	PT - office	UG	Considers her diet healthy except for treats, tries to keep active with exercise classes, wants to lose weight
PH	PA	67	M	27	Retired	A-level	Diagnosed with T2DM and well-informed, wants to lose weight but happy with his own methods
NC	PA	42	F	24	PT - office	PG	Interested in health and nutrition, wants to be more active but finds it hard to fit in exercise
MB	PA	47	M	30	FT - manual	GCSE	Considers his current diet and PA good but aware he needs to lose weight
BH	PA	74	M	34	Retired	UG	Has osteoarthritis, recognises his PA is low and he needs to lose weight, happy with current diet
VJ	PA	37	F	24	PT - office	PG	Aware she is not active and her diet could be better

3.3.2 Overview

In general, the participants found the evolutionary mismatch concept to be an acceptable and interesting frame for delivering health information. Findings are presented here in the following sections: potential facilitators for using the mismatch concept; potential barriers for using the mismatch concept; preferences for and understanding of resources; and Questionnaire 2 results. Within the first two sections, illustrative data is drawn mainly from the thematic analysis of interview transcripts. The third section presents findings from the questionnaires and Framework matrices. The fourth section summarises the findings from Questionnaire 2 relating to the effects of the resources in the week after the interview.

3.3.3 Potential facilitators for using the mismatch concept

Table 3.3 sets out the themes and sub-themes within this section which were drawn from the thematic analysis of the interview transcripts and questionnaire responses.

Table 3.3 Themes and subthemes identified as potential facilitators for using the mismatch concept

Theme	Sub-themes
1. Explaining *why*	1.1 A reason to act
	1.2 Explains without blame
2. Contrast	
3. Novelty	3.1 Novelty stimulates interest
	3.2 Novelty makes me think about things differently
4. Familiarity	
5. Reflecting on personal past	

3.3.3.1 Theme 1 - Explaining why

By showing how and in what environments humans have evolved, many participants felt the resources gave a deeper understanding of "*why we are what we are, why we do what we do" (MS)*. This was considered to be important since it gave powerful support to the healthy living messages:

> *Going right back to look back at our ancestral diet and the way our body is evolved, gives you a real understanding of 'why?' And I think people need to know why, for it to have an impact... or otherwise it's a set of rules (LL)*

> *I think they explain why movement is so important in more detail, because it's not just talking about move around more to lose weight and to avoid type 2 diabetes, but it's explaining that the human body is designed to be moving a lot in order for it to function properly (SL)*

That is, explaining *why* seemed to give a stronger reason for making behavioural changes and some participants explicitly highlighted that this gave them a greater impetus to act:

I'm somebody who really likes to understand something to be motivated as to why I need to do anything differently (NC)

If you feel you're doing something to help yourself and you understand why you're doing it, it's much, much more pleasurable. (PW)

It was also highlighted, particularly in relation to the information on evolved taste preferences and fat storage, that, in explaining *why*, the resources were not attributing personal blame but helping people to understand behaviours and how the body copes:

It was understanding that it is not just an irrational reaction to fatty foods. That there is a reason for it. (TS)

What I've hooked on to throughout this is it's not about blame, it's about understanding, and knowing where that's come from, and the reasons for it (MS)

3.3.3.2 Theme 2 - Contrast

This theme was closely related to explaining *why* and the concept of giving a reason to act. The comparisons drawn between modern and ancestral lifestyles were highlighted as stark and this seemed to help people understand the need for healthy behaviour change:

I think putting the contrast between, for example, the amount of sugary food that we had, and now suddenly, in literally the space of, like, a few generations, it's so completely contrasting, I just think it helps you to understand some of the background of why. (RA)

Several graphics seemed to be particularly good at depicting a *"compelling" (DJ)* contrast as participants drew visual comparisons between the ancestral and modern elements:

The comparison really, of what we're eating today and it looks really bad when you show it in the comparison – it's obviously so processed (JG, diet graphic 1)

This one is more shocking because you go down the apples bit and then you suddenly come up the colouring agents – flavouring agents I mean (PW, mismatch concept graphic: Lists - Apples)

Free-text responses to Questionnaire 2 indicated that the impression of a stark contrast was something that stayed with many participants in the intervening week. For instance, to the question 'What information, if any, particularly made you think or has stayed in your mind?' some responses were:

What stuck to my mind is the idea that… caveman ate more greens/ less rich food and moved more, modern man eats more rich food and moves less.

The amount of sugar consumed by our 'ancestors' vs. in modern life

Just how much activity we have historically done and how little we have to do today

> *The amount of sugar we eat in the modern diet (20kg) compared to the ancestor diet (2kg)*

3.3.3.3 Theme 3 - Novelty

The evolutionary mismatch concept was perceived by all participants as novel, although four people did highlight that the health messages (*"eating the right things and not eating too much and moving more" (TS))* were not new. A further person, JG, mentioned that she had *"read about a Paleo diet or something like that in the past but I haven't really seen any of that promoted in this way before".* Importantly, the novelty of the mismatch concept helped to stimulate interest both by virtue of presenting information in a 'new' frame and by providing specific facts or details that people had not heard before:

> *I had never thought about the adaptive genes bit. I guess that whole bit I didn't really know much about. So I guess that's why I found that whole bit quite interesting. (PL)*

> *The focus is on how our current lifestyles differ from the lifestyles that our bodies are still designed to cope with – that's not something I've come across as a simple message like that. (PH)*

> *I had no idea that we couldn't digest milk 10,000 years ago, I wasn't aware of that but that's a very interesting fact. (DJ)*

> *I didn't have a feeling for the time-scales at all, and that was useful and interesting information, and completely germane to your message. I'd be happy to read more about that stuff. (FB)*

The novelty of presenting information in an evolutionary frame also prompted many people to think about the health messages in a new light:

> *It makes that resonate in a deeper way that you didn't perhaps… that hasn't been presented to me in quite the same visual way before, that makes me think about it in a different way. (LS)*

> *That was very useful, because I hadn't have thought of that before. I was just thinking of today and how to get fit and less weight. And I was concentrating on that. I didn't realise, I didn't think about the evolution trail that we have gone through and that illustrated it to me very well. (BH)*

Free-text responses to Questionnaire 2 indicated that the facts that were novel to participants were also the ones that they reported to have stayed in their minds over the following week.

3.3.3.4 Theme 4 - Familiarity

Although the evolutionary aspect was acknowledged as novel and all participants highlighted certain facts or ideas in the resources that they had not known before, when asked how the texts fitted with their prior knowledge, many participants responded that it wasn't new information:

> *I wouldn't say there's anything in there where I thought, 'My goodness I didn't know that before'. But reading it all in one place, it is quite interesting… there was nothing there that is either fresh or it challenges what I thought I knew the situation was. (PH)*

> *It's not new but it made me realise it again. (SK)*

> *It was stuff that I'd known or was aware of, not necessarily known details of, but I was aware of certain things. (MB)*

It seemed that because participants were aware of, for example, humans evolving from apes and living as hunter-gatherers, the overall impression was that the information was familiar and the new facts or details were simply accepted, i.e. went unchallenged. This was particularly the case with the introductory mismatch concept text.

3.3.3.5 Theme 5 - Reflecting on personal past

While the comparison between ancestral hunter-gatherer lifestyles and those of modern day was highlighted as compelling due to the scale of difference (see section 3.3.3.2), several resources discussed the more recent past as well (i.e. twentieth century) and this led some participants to reflect on their own lives or think about older relatives:

> *When I was at school - I was born in the fifties – I remember … people would have a big breakfast, a big lunch, they'd have tea in the afternoon, they'd have dinner and then they would have something to eat before they went to bed … And people weren't fat then. I used to walk to school, I used to play – there were no such things as computers or anything like that, so it seems to me that perhaps it is the mass use of cars and all the other things that we now have that mean we don't even have to go out to get our pizza – we have it delivered. (TS)*

> *Now we can just go to the shop and pretty much everything is either high sugar, a high sugar drink, a high sugar snack, or a high carb something, isn't it? And I thought going back in time it wouldn't have been like that, you didn't have all those sugar options. So although people are, you know- my grandparents, they probably ate a lot but it wasn't these really highly sugar calorific foods. (LL)*

Reflecting in this way also helped people see the need for change or, as TS went on to say, "*I think it is a very good kick up the backside*". Indeed, another participant (DJ) felt that the more recent changes should be emphasised more.

3.3.4 Potential barriers for using the mismatch concept

Table 3.4 sets out the themes and sub-themes within this section, which were identified through thematic analysis of the interview transcripts and questionnaire responses.

Table 3.4 Themes and subthemes identified as potential barriers for using the mismatch concept

Theme	Sub-themes
6. Interference	6.1 Negative elaboration 6.2 Too simplistic 6.3 Misconceptions
7. Already healthy	

3.3.4.1 Theme 6 - Interference

Related to the theme of familiarity (see section 3.3.3.4), there were instances where participants brought in prior knowledge or beliefs which challenged information provided in the resources. For example, several people commented on the recent media coverage of the negative effects of sugar for health; when looking at one of the diet graphics (food type circles, Appendix 3.1e), however, the relative size of the circle depicting sugar intake was felt to imply that sugar is not a big problem in today's diet:

> *Because it's [the circle] relatively smaller than some of the other ones, I think... I've said, looking at some of the other things, that the idea of sugar and really high energy rich foods is something that strikes with me, but I think in this one it maybe doesn't have such an impact about the sugar. (RA)*
>
> *I mean sugar, that's the one that seems to come across here as being not much more significant than fats and oils. And I think we're being told 'no, this [sugar] is much more significant than fats and oils'. (TS)*

Several people acknowledged that life expectancy is greater today than it has ever been before, and while in most cases this was not seen as negating the mismatch message, it did cause a couple of people to question the idea of using ancestral lifestyles as a guide for modern day (negative elaboration):

> *We are eating more sugar nowadays than we were back along, but then again, there's two sides of that argument. You hear on the news nowadays that mankind is living longer, we're living longer than we used to. Well, we used to do this, we used to have this much sugar, so what's wrong? Is more sugar keeping us alive, because we're preserved? (MB)*
>
> *We increase that life expectancy through various means including health care, the way we live and dangers, less accidents; yes there's an issue with these heart and bone, muscle, flexibility issues but overall lifestyle has improved and longevity being healthy has increased enormously so there's a balance between all those issues (DJ)*

In DJ's case the comparisons drawn between ancestral and modern lives led him to conclude "*how good [the] modern lifestyle is".*

Another example of negative elaboration stemmed from the text about human digestion of cows' milk. The introductory mismatch concept text gave the ability to digest milk beyond infancy (i.e. lactose retention into adulthood) as an illustration of one of the few occasions of rapid evolution in humans. However, this caused a few participants to question whether they should be consuming dairy products, which was not a message the resources intended to give. These participants seemed to be bringing in information they had heard from other sources about food intolerances and allergies:

> *SL: Maybe I should think about whether I should be having dairy, milk and stuff like that. I mean, I know it does say that our systems have evolved to cope with it, but I wonder a bit, well, would I be better off without it? Would I notice any benefit?*
>
> *Interviewer: What makes you think that?*
>
> *SL: Well, I know that some people get bloated from having wheat or yeast. I think there's some molecules in… is it lactose in milk that people don't digest?*

Bringing in prior knowledge also led some participants to feel that the resources were too simplistic. One of the diabetic participants, PH, felt that, in highlighting the environmental changes through evolution, "*the implication in this is that it's exclusively lifestyle choice and that's not necessarily the case".* PH wanted to see *"the genetic component of type 2 diabetes"* mentioned. Another of the diabetic participants, FB, also felt the resources were giving an incomplete picture:

> *I don't see how I verify that the evolutionary sweet-tooth causes diabetes, and indeed it's clearly not the whole story, because I have diabetes and you haven't. (FB)*

In this case, FB wanted to see more "*evidence"* or a *"mechanism"*; interestingly he interpreted the resources as *"asking me to believe a narrative about why I am a type 2 diabetic".* This perhaps led him to question the information more than the other participants.

A final important but uncommon instance of interference occurred when participants held inaccurate beliefs, which they felt refuted the information provided in the resources. A couple of participants highlighted misconceptions about energy content of foods, confusing vitamin and mineral content with energy density. This led them to question the information provided regarding scarcity of energy rich foods for hunter-gatherers:

> *The energy rich foods were scarce - why were they scarce? Blueberries are high in energy, broccoli is, kale. (MB)*

3.3.4.2 Theme 7 - Already healthy

Several of the graphics used highly processed foods and drinks (i.e. extreme examples) to exemplify the modern lifestyle and among the present sample this proved to be potentially counter-productive as many participants responded that these products were not typical of their diet:

> *You're telling me this is what I eat, and I look at you and say "No, it isn't." (FB, diet graphic: Food type circles)*
>
> *That doesn't apply to me because I just drink that, I don't drink Coke, I just drink lots of water. (MB, mismatch concept graphic: Lists - Drinks)*
>
> *It makes me feel slightly better because I never go to- there's a McDonald's drive-thru at my Sainsbury's ... We don't- it's not part of our lifestyle to eat takeaway or burgers or coke. (NC, mismatch concept graphic: Timeline)*

As illustrated in these quotations, there seemed to be a danger that participants would dissociate themselves from the modern lifestyle depicted in the graphics. Among some participants this led to a feeling that they are already healthy and therefore might not feel a need to change:

> *Looking at that picture of all these sweets, made me think… made me feel quite, not smug, but comfortable – yeah, I'm okay with that. I don't eat a lot of that. (MS, diet graphic: Sugar preference storyboard)*
>
> *I don't really eat apple pies and stuff either or fizzy drinks so- I suppose the danger is that I think, 'oh no, I'm ok really.' (VJ, mismatch concept graphic: Lists)*

On the other hand, this might not necessarily be a problem as some participants highlighted that they felt pleased that the resources were "*backing up that I'm doing the right thing" (RV).* Also, although many participants initially responded, particularly to the mismatch concept graphics, that they had a healthy diet, as the interviews went on, they did admit to consuming less healthy items. For example, when first viewing the Lists graphics (Fig.1C), PW reported:

> *I won't eat anything with flavourings in them anyway, so everything is very natural for me and I don't drink fizzy drinks and sugar laden things, um I don't do takeaways either. (PW)*

However, when later discussing the introductory text she went on to divulge her liking for chocolate:

> *I am a healthy eater, I am, I do all my cooking and we cook every day for ourselves, we don't buy any processed food, so it's all fresh. [pause] However, there are things (laughs) like chocolate and whatever (laughs) that just are there and they're delicious and you think 'oh sod it' (PW)*

Thus it seemed that many participants viewed their diets as healthy but that what was included in their idea of their diet was not actually everything that they ate:

> *I do homemade meals, I don't buy ready meals, or I probably only have a takeaway maybe once every two weeks. I think where I come unstuck is treats like chocolate. (SL)*

> *If there's one thing, I suppose, alcohol's the one thing that falls outside of my good control, you know, I tend to overdo it on that sometimes. But otherwise, I think we've got a balanced diet. (MS)*

> *You just do it because it's part of the day, but actually yesterday I had a flapjack full of golden syrup for breakfast, I had a Kinder Bueno in the afternoon then I had an ice cream in the evening. That's three things, and that's actually quite bad, over a week I probably do that a lot [laughs] whereas my actual meals are really healthy. (LL)*

A few participants commented at the start of the interviews that they felt their activity levels were already high and could not or did not need to be improved:

> *Because I'm constantly active, I'm not sat on my backside doing nothing. I am constantly active. Believe me, there's days I'd like to be inactive, but I'm always on the go. (MB)*

> *I couldn't be more active, I don't think, than I am at the moment. Because I don't want to go running anyway, but I am pretty active, all day. (PW)*

However, as the interviews proceeded these participants again reported that the resources were lending support to their current activity levels or had highlighted aspects of activity that they had not previously thought about, thus making them consider ways they could be more active:

> *I'll think more now when I'm sort of moving around, be happier doing the extra movements, if you see what I mean. (PW)*

> *It does make me think that it's not just moving that you need to do but there's also different types of movement in order to exercise different organs… I think I'm too focused just on trying to slim down rather than thinking about all the other benefits. (SL)*

3.3.5 Preferences for and understanding of resources

This section presents findings from the questionnaires and Framework matrices (although some longer quotes from interview transcripts are used here to illustrate issues that were summarised in the matrices).

3.3.5.1 Mismatch concept graphics

Figures 3.2-3.6 display results from Questionnaire 1 (delivered immediately after the interview and viewing of the resources). These figures give participants' ratings of the four mismatch concept graphic styles on the following five factors: degree to which it grabbed their attention, attractiveness, ease of understanding, interest generated and personal relevance. To facilitate comparison of the different styles, the two positive rating categories (e.g. quite interesting and very interesting) for each factor were combined. Overall the Lists style (Fig.3.1c) received the most positive ratings on all factors except personal relevance, for which the Timeline style (Fig.3.1a) received one more positive rating.

Figure 3.2 Ratings of mismatch graphics for their ability to grab attention

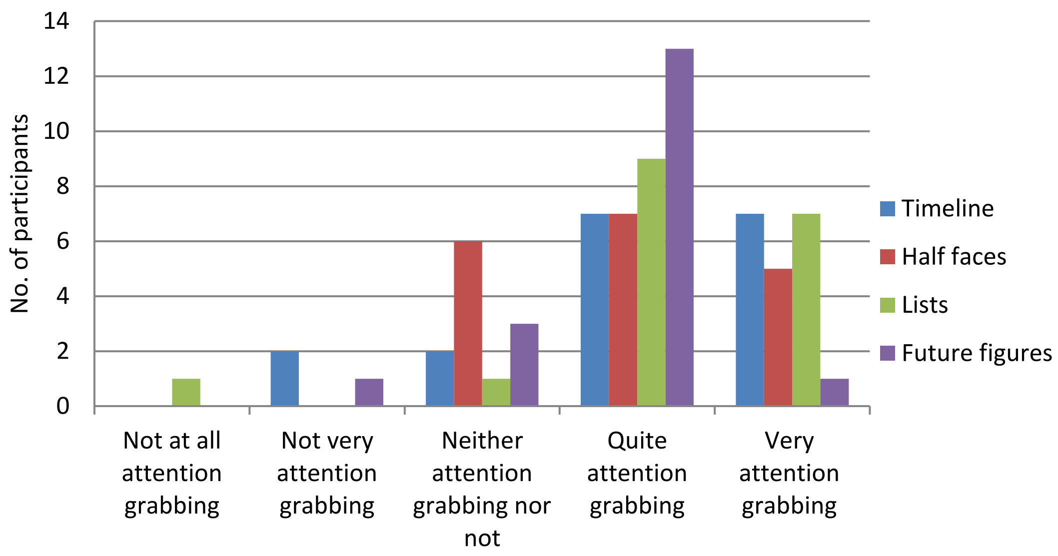


Figure 3.3 Ratings of mismatch graphics for attractiveness

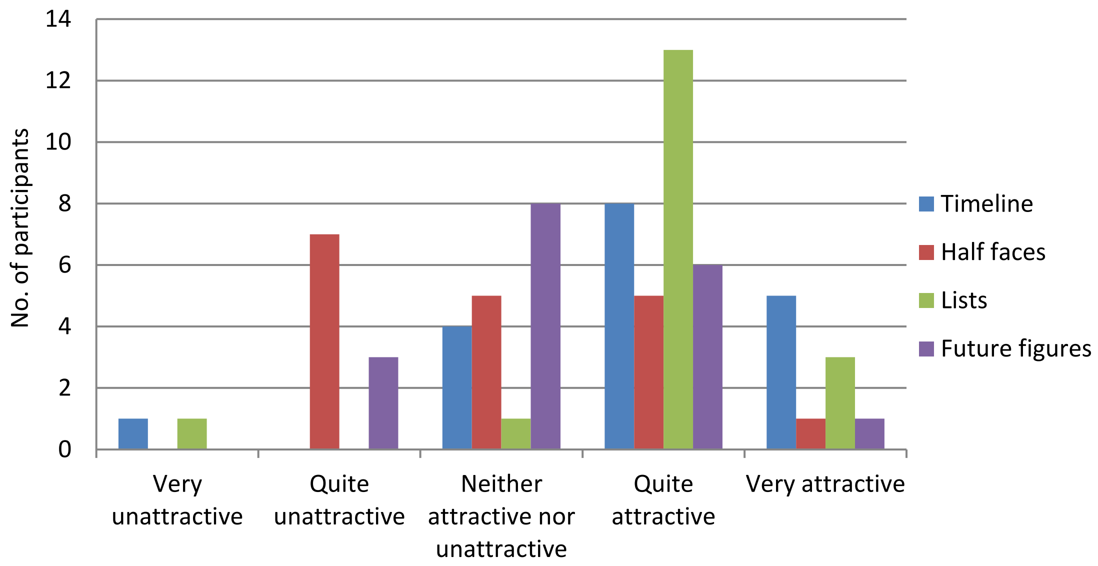


Figure 3.4 Ratings of mismatch graphics for ease of understanding

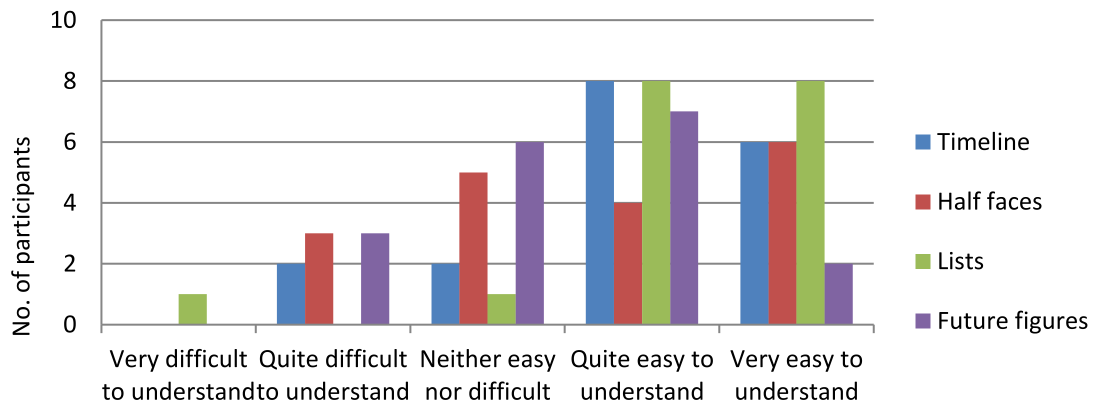


Figure 3.5 Ratings of mismatch graphics for interest

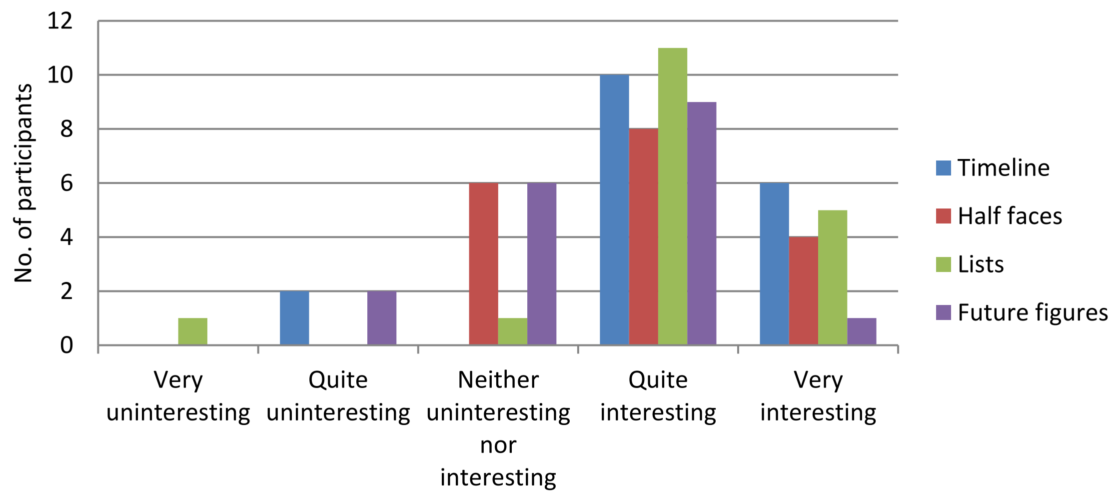
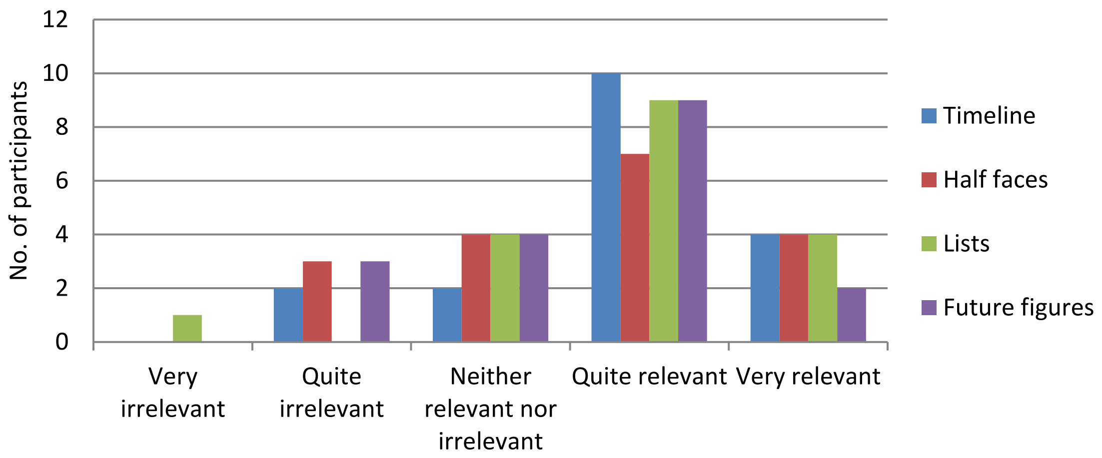


Figure 3.6 Ratings of mismatch graphics for personal relevance



The sample was divided as to whether the 'word' Lists graphics (Apples and Hunting) or the pictorial Drinks List graphic were better, with the majority preferring the former. The visual simplicity and the use of a single bold colour in the Apples and Hunting Lists graphics were features that participants highlighted as appealing and having grabbed their attention. The pictures of glasses of water in the Drinks List graphic were appealing to some, but others felt their lack of colour made them *"not very eye-catching" (PL)*. The vertical line of repeated words created an obvious focus and drew people's gaze to the text at the bottom of the page. Several participants remarked that the Lists gave an impression of a timeline, although this impression was stronger in the words Lists. The message in these graphics was not instantly apparent but they seemed effective at generating interest and the meaning was quickly conveyed:

> *Your eyes get snagged by the long list and you think 'What's going on?' so you carry on reading. (FB)*

> *If you just saw the print on a billboard at the side of the road, you wouldn't get it, but you would want to know more. (MB)*

One participant (BH), however, was not interested by the Lists graphics, stating that they were *"repetitive"*. Although BH read the tagline ('We haven't evolved for this'), he did not seem to relate this to the repeated words or pictures. One other participant (RV) also did not seem to take an evolutionary message from the Lists graphics, although he did report taking a clear health message, particularly from the Drinks List:

> *This is, obviously, just water, water, water, water, which is obviously healthy, but when you go to that, I presume it's Coca-Cola…but it could be any sort of fizzy soft drink. And it's all the additives that are in it. And that came across quite clear. (RV)*

A few participants initially associated the Hunting List graphic with anti-fox-hunting campaigns, due both to the word ‘hunting’ and the black background, which a previous Greenpeace campaign had used. Although this could potentially cause people not to attend to the graphic further, depending on their attitude towards fox-hunting, participants in this study reported that the ambiguity of the word ‘hunting’ made them want to find out more.

The use of the word ‘adaptations’ in the text at the bottom of all three Lists graphics was puzzling to some. Not having read the expository texts before viewing the mismatch graphics, it seemed that these participants were unclear what ‘adaptations’ meant:

> *I personally don’t understand that - ‘the adaptations’… The adaptations of what? (LL)*

> *The bit that said ‘the adaptations that helped us are now causing chronic diseases’ I couldn't quite make sense of that, because I couldn’t interpret what it meant by ‘the adaptations'… you think about humans developing, say, being able to run fast and being strong … and now it’s shopping and then you may get takeaways. I would see those things as a kind of like convenience rather than a physical evolution or adaptation. (RA)*

Despite this, these participants were still able to take an evolutionary health message from the tagline, graphic and other sentence in the text on the graphic (‘Until very recently humans had lots of activity and not much sugar’). Overall, twelve participants reported that they liked the Lists graphics (or one particular List graphic) best out of the four mismatch graphic styles and a couple of participants reported, in Questionnaire 2, that these graphics had stayed in mind after the interview.

The Timeline graphic was also generally well received and understood. Many participants found the pictures attractive and attention grabbing due to their colour, although to some they seemed *“a little childish” (PW).* The central line down the centre of the graphic helped to draw the gaze of some participants down the page to the tagline (‘Our world’s evolved dramatically, our bodies haven’t’); but for others, the line was confusing as it divided the graphic into two columns that were read separately. The Timeline received the most positive ratings of all the mismatch graphics for personal relevance and this may have been because it incorporated several topics (sugar intake, sedentary behaviour, take-away food intake etc.). Different participants found different topics in the graphic chimed with them. On the other hand, including all the different pictures, as well as the line and captions, made this graphic less appealing, for some people, as it took longer to interpret and appeared *“too complicated” (DJ)*. The amount of visual information in this graphic also seemed to distract from the two diametrically opposite headlines (*'3kg of sugar a year'* and *'3kg of sugar a month'*) leading a few participants not to notice that they were different and so take an unintended message:

> *We're eating 3kg of sugar a year. But is that a problem? Dunno, doesn't sound like a huge amount. (DJ)*

The Half Faces graphics (Fig.1b) received very mixed responses. A few participants found them *"powerful" (MS)*, mainly due to the eyes of the faces, whereas others, who also found the faces attention grabbing, felt the eyes and brown tones made the graphics off-putting and *"scary" (NC)*. In contrast, some participants found the Half Faces *"a bit dull" (PL)* because of the colours. It was not immediately apparent that the two halves of each face depicted an ancestral human and a modern human, and so participants had to infer this from the headlines. Many participants suggested that the half faces should be made to look more obviously from different eras, but opinions differed as to how this should be done: making the modern half *"clean looking, looking healthy" (DJ)*, or make it more obviously unhealthy, or use an extra visual cue, *"something like a spear" (PL)*, alongside the ancestral half. Interestingly there were two mentions of the Half Faces graphics in the open responses to Questionnaire 2 and both participants mentioned that they found it surprising that these graphics had stayed in their minds as they "*didn't like"* them.

The Future Figures (Fig.1d) were the least successful of the mismatch graphics: the bold headlines and colourful pictures helped to attract attention but the interviews highlighted that the meaning of the graphics was unclear. The Future Figures graphics took a different approach to conveying the concept of a mismatch in that they showed hypothetical adaptations that might make the body better suited to our lifestyles. These were not intended to be attractive or realistic possibilities, rather they aimed to illustrate that currently the human body is not well adapted to cope with the modern lifestyle and, further, prompt people to feel that it would be better to change lifestyles rather than the body. However, some participants felt the graphics were suggesting how we *should* evolve, prompting responses such as, *"why would anyone want to sit down all day?" (PW)*. Others felt that the graphics were contemplating future innovations in engineering and medical science and that some of the suggestions would be positive:

> *'Super thick blood vessels' - I've got high blood pressure so… interesting, you know. That means I could live longer. (BH)*

There was also confusion as to whether some of the proposed adaptations were features that humans already possessed (e.g. "*I didn't know we had five sets of teeth, I thought we only had* *one" (TS)*). Of the participants who did understand that the proposed adaptations were hypothetical and not meant to be attractive, the meaning of the graphics was still not clear:

> *I just don't think it's really saying anything … I mean it's kind of a bit unrealistic, 'our bodies have hardly changed…how could we bring them up to date?'. Well, we're never going to have five [sets of teeth], it's just a bit silly. (JG)*

Some participants also commented that the Future Figures graphics promoted negative affect:

> *It makes me quite despondent because I think that's not going to happen. (LS)*

Thus, although the Future Figures graphics did highlight to some participants that the human body is not well adapted to the modern lifestyle, they were not effective at also prompting these people to feel that a change in lifestyle would be beneficial and more desirable than changing the human body.

3.3.5.2 Physical activity and diet concept graphics

These graphics were less well developed than the mismatch concept graphics and participants suggested ways in which they could be improved in future iterations. For example, participants found some of the more complex graphics hard to navigate:

> *I wasn't sure which bit to look at first and which way to read it (VJ, Physical activity comparison table, Appendix 3.2a)*

Using cues, such as arrows or text to direct people's reading, was suggested in order to rectify this. The Fat cycles graphic (Appendix 3.2h) seemed to provide such cues and participants found it easy to navigate.

In general, including pictures depicting people in different activities seemed to make graphics more personally relevant:

> *Yep [that's] absolutely, the problem I have today, absolutely – sitting on our bottoms all day, both at work and then when we go home. (DJ – on viewing Physical activity comparison graphic, Appendix 3.2c)*

> *The person on the scales going, 'Ahh!' [Laughs]. Because when I go on the scales, I always think, 'Ahh! I want to lose weight!' So that's the one that made me have a little wry smile. (RA – on viewing Fat cycles graphic)*

The pictogram style of picture, used in the Fat cycles graphic, was particularly well liked and, as with the mismatch graphics, the more colourful diet and physical activity graphics were more attractive.

Most of the graphics seemed to be understood as intended and, with further development, participants generally felt they could sit well alongside the expository text. However, the muscle and sugar infographic (Appendix 3.1d) was not well received or understood. This graphic contained several diagrams, accompanied by a small amount of text, which aimed to explain how a low proportion of muscle tissue in the body can lead to high levels of sugar (glucose) circulating in the blood, in turn damaging blood vessels. Several participants felt the diagrams gave the impression of a "*biology textbook" (SL)* which was immediately off-putting. Few people were able to relate the graphic to themselves, possibly due to the 'scientific' diagrams:

> *Initially I didn't know what these- was, it's a cross-section of a thigh, isn't it? I wasn't sure what that was straight away. I mean it is labelled but you don't often see your thigh like that do you (laughs)? (VJ)*

> *I don't like those [thigh cross-section] at all. I can't relate that to a part of me. (PL)*

All but one of the participants who saw the muscle and sugar infographic felt that the graphs on it, showing sugar uptake by muscle and fat tissue, were confusing and several participants stated that they *"skimmed over"(MB)* them. There was also a tendency to skip the blood vessel diagrams at the bottom of the infographic, although this was because participants assumed they were illustrating cholesterol build up, which was a message (and image) that they were already familiar with. This in turn led to some misinterpretations of the graphic:

> *So the top is easy to understand and so is that [blood vessel diagrams], I mean we're familiar with cholesterol-related type things (DJ)*

> *Sugar in my blood, which is laid down as fat into my arteries, forms into plaques and gives me a heart attack. (PW)*

> *Blood flows freely [ancestral blood vessel] and blood flows slowly [modern blood vessel]. Because of the fat, effectively… Clogs up the arteries. (BH)*

As mentioned in section 3.4.1, the food type circles graphic (Appendix 3.2e) also gave some participants an unintended impression: that sugar is not a problem in the modern diet. This graphic was also confusing to some participants because it was *"a little bit too much to take in" (TS)*:

> *I can extract information from this, but it doesn't feel a completely helpful way of doing it… I'm supposed to get some information from what the graphic is, and also information about the size of the graphic, and these two things don't play enormously well together. (FB)*

The pie charts used on the sugar preference storyboard graphic (Appendix 3.2f) were reported to be easier to understand and generally preferred.

3.3.5.3 Expository texts

All participants felt the texts were easy to read and understand, although there were some parts that a few people suggested could be made more concise (e.g. the two bullet-pointed statements on page one of the introductory text) or where explicit clarification of terms was needed (e.g. a sentence at the end of paragraph two in the introductory text to say 'these are called adaptive genes'). Participants differed as to which parts they found interesting, depending on their prior interests or what was new to them (see section 3.3.3), but everyone found something of interest in each of the texts. The expository texts prompted most participants to think about their own lives and what changes they could make,

> *It makes me think that I need to do more physical activity, and that I can probably do more incidental exercise as well as actually setting aside time to do it. (SL)*

> *For me, the key point was that I need to be eating more high fibre food. (LS)*

The PA and diet texts ended with some advice on behavioural changes that could be made and these were generally found to be helpful:

> *I think that the tips at the end, rather than just telling you 'oh this is all terrible', actually having tips at the end and how you can improve your lifestyle, really helps, especially as they're quite achievable things as well. (VJ)*

However, many people felt that more advice was needed and participants gave several suggestions for further information that would be useful to them, including examples of foods swaps, recipe suggestions, more tips on ways to increase daily activity, information on food groups and nutrition labels. Without further information or support, some participants indicated that the texts might leave a negative impression:

> *One of the things I'd take from it was thinking 'oh my diet's really bad' even though, you'd just think, it's an ordinary diet. Maybe if the good things were promoted more … make more of the good diet [i.e. potential healthy modern diet], as opposed to saying how bad the current diet is. (JG)*

3.3.5.6 Narratives

Both narratives received very positive responses from all participants. The characters came across as believable since participants could either relate to them personally or thought they were similar to their friends or family members:

I felt it was believable because it sounded just like some of the things I'm doing. (NC, physical activity narrative)

I know lots of women who've spent large amounts of their life battling with their weight… So, yeah, I have some sympathy for the start of the story and how she's feeling. (FB, diet narrative)

As illustrated by the above quotations, the gender of the characters did not seem to affect the ability of the narratives to engage readers of the opposite gender (e.g. NC is female but the PA narrative was about a male character, John. Likewise, FB is male and the diet narrative concerns a female character, Cathy). The *"chatty, Woman's Own style"* of prose also helped to make the narratives *"read like a real person" (LS)* and several participants highlighted that they liked the use of humour. Participants viewed the characters positively and this seemed to help make the narratives engaging too:

I'm really happy for him [John]. I think he has been really sensible about how he's done it. (PW, physical activity narrative)

I liked her, and I thought she was somebody very like myself, so I did immediately- there was an empathy there. (LS, diet narrative)

The changes made by the characters seemed achievable and credible:

All the things you've done here is sensible, go back to basics again, and that is completely believable. (RV, diet narrative)

It makes sense to me that it is these changes… I think that if you go through saying you're on a diet, then it seems to me that is going to be temporary… the only way it will ever really work is – as the story says here – you make changes that you can live with. (TS, diet narrative)

He's doing things that aren't overwhelming, where people are going to think, you know, 'I'm never going to be able to do that'. He's doing things which are quite achievable. (SL, physical activity narrative)

For those participants who felt that they could make changes to their activity levels or diet, the achievable nature of the changes that the characters made seemed inspiring:

Lifestyle changes have always appeared to me to be too difficult, or too huge to actually embark on. Whereas this is quite tangible and it feels doable for the first time. (LS, diet narrative)

It made me feel- those are quite small things he's done, but perhaps I could do small things in a similar way. (PL, physical activity narrative)

However, a few participants highlighted issues that the narratives did not address, including maintaining dietary changes, particularly in different social situations, and exercising when limited by conditions such as arthritis. It was suggested that more narratives, dealing with these issues, might be helpful. Overall, the narratives seemed to be a useful supplement to the other resources, *“bringing together those ideas” (TS)* and giving a *“positive message” (VJ)* by helping people to see that small, achievable changes could improve their health.

3.3.6 Questionnaire 2 results

Responses to Questionnaire 2 (delivered one week after the interview) indicated that the resources had prompted participants to think, after the interview, about making healthy behaviour changes; and some participants had even made some changes as a result (see Figures 3.7-3.9). The changes that participants reported making were in line with the information provided and included: cutting down on high-sugar foods (n=3) and salt (n=1); increasing the amount of vegetables consumed at meal times (n=2); and increasing PA (n=8).

Figure 3.7 Responses to Questionnaire 2, by study condition (diet or PA) - Over the past week, has the information in the interview made you think about the things you do in your own life?

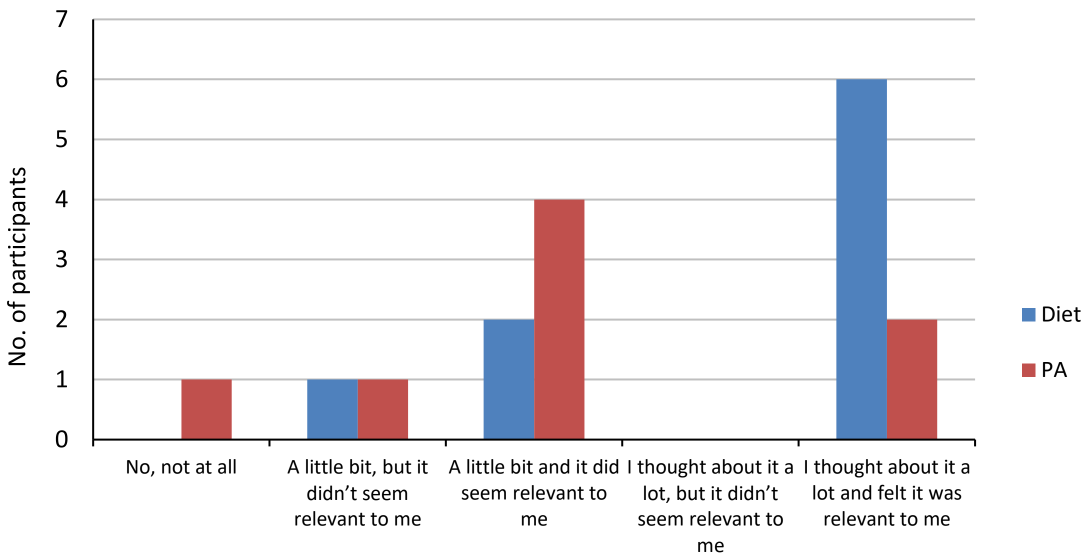


Figure 3.8 Responses to Questionnaire 2, by study condition (diet or PA) - Have you thought about making any changes to your diet or activity levels as a result of the information?

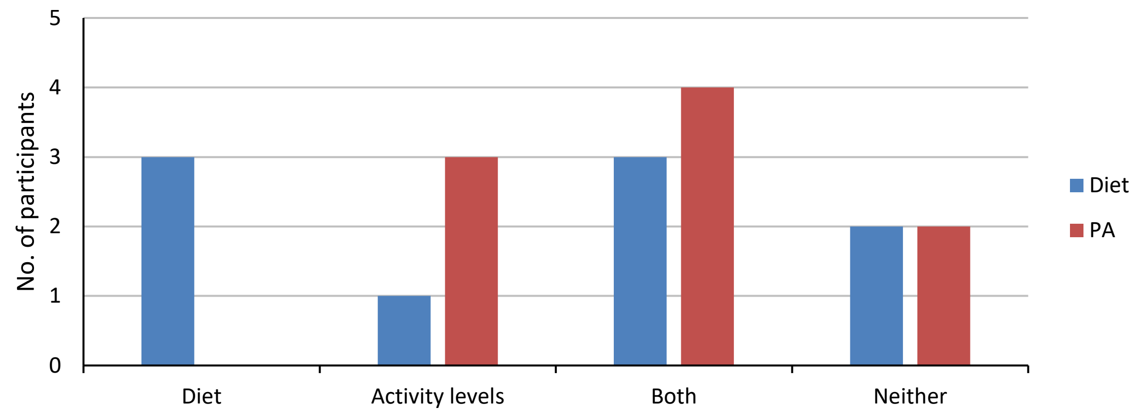
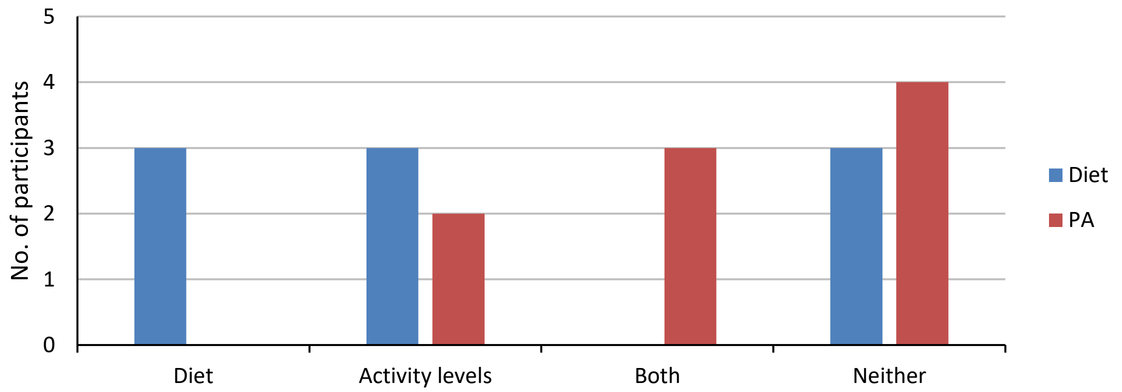


Figure 3.9 Responses to Questionnaire 2, by study condition (diet or PA) - Have you made any changes to your diet or activity levels as a result of the information?



3.4 Discussion

This study was part of a first, exploratory stage in the development of an intervention to support healthy behaviour change by promoting a deeper understanding of how PA and diet influence health. The study aimed to explore the potential of using the evolutionary mismatch concept as a frame for delivering detailed health information and also to explore the relative potential of a set of mismatch-based resources to deliver information in an interesting, easily understandable, personally relevant and memorable way. This section will first discuss the findings from the interviews and questionnaires with respect to the second aim and then look at the potential of the mismatch concept and broader implications, drawing on previous research.

3.4.1 Performance of mismatch concept graphics

The mismatch concept graphics were intended to generate initial interest, that is, to act as a 'hook' to encourage viewers to read on and engage with the other resources. Presenting these graphics at the start of the interview helped to test their novelty and complexity, as participants had not yet seen any of the texts or been asked about evolution or health. Questionnaire 1, presented immediately after the interview, showed that two graphic styles (the Lists and Timeline) performed best overall in terms of their perceived ability to grab attention, attractiveness, ease of understanding, ability to generate interest and personal relevance. The interviews gave a deeper understanding of these perceptions, for example, identifying what exactly in the graphics was considered attractive or personally relevant. With regards to understanding, the interviews highlighted that the Future Figures style could be misinterpreted, but this was not evident in the results of Questionnaire 1, where only a few participants rated the style as difficult to understand. The combination of Questionnaire 1 and the interviews therefore seemed to work well towards the aim of understanding the potential of the mismatch concept graphics, each providing unique insight, and the findings will help to inform future iterations of the graphics.

Overall, the results seem to lend support to the novelty-complexity appraisal theory of interest (Crutzen & Ruiter, 2015; Silvia, 2008). The Lists graphics, for example, were sufficiently complex (in that their meaning was not instantly clear) to make participants want to attend to the graphics and ascertain their meaning. The Timeline graphic, however, appeared to some as too complex, due to the number of items included, and this led them to skim over parts. The findings are also in line with the literature on ease of processing and positive affect (Meppelink et al., 2015; Song & Schwarz, 2010; Wright, 2012); for example, the Lists graphics received the most positive responses and, although their meaning was not immediately obvious, participants generally felt they could make sense of the graphics quickly. In contrast, participants seemed to find the Future Figures graphics less easy to understand and they were not well liked.

The presentation of the graphic styles one at a time and in an isolated research setting does not enable conclusions to be drawn about how the graphics would perform in a real world context. For instance, although the Lists graphics were generally reported to be attractive and attention grabbing, in a setting with other objects competing for an individual's attention the graphics might not be sufficient to prompt a person to attend to them for long enough to understand their message. To provide a more accurate idea of which graphic generates most interest, all the graphics could be presented at once, to see which one participants are attracted to and look at first or for longest or, if viewed as the cover of a booklet, which booklet they would pick up to read. However, the interviews did provide a suitable means of exploring whether the graphics conveyed the concept of an evolutionary mismatch and, importantly for this first phase of intervention development, highlighted which elements of the graphics enhanced or decreased their performance.

3.4.2 Performance of physical activity and diet concept graphics

These graphics were designed to illustrate various points covered in the expository texts. As for the main concept graphics, the interviews enabled exploration of the specific elements in the graphics that aided or detracted from clearly conveying the intended messages, which will inform further development of the resources. Presenting them separately from their respective texts was helpful for testing whether they could 'stand-alone' without the need for the expository texts. The findings suggest that for some of the more complex concepts (e.g. the importance of muscle in glucose metabolism) the graphics were not as easily understood as the texts. Even for the simpler concepts (e.g. comparison of ancestral and modern muscle proportions) participants considered the texts helpful for clarifying what they had seen in the graphics. Thus the findings suggest that these graphics should not replace the expository texts, rather they could be presented alongside the relevant text to attract attention, aid encoding of concepts and thus enhance recall (Houts et al., 2006). This is in line with previous research that has found text communications to be more comprehensible than pictorial, audio or audio-visual communications relating to complex health messages, particularly for older people (Bol et al., 2016; Byrne & Curtis, 2000; Chaiken & Eagly, 1976).

3.4.3 Performance of expository texts

All participants viewed the introductory mismatch concept text; half the sample also viewed the PA text and the other half saw the diet text. This was necessary to keep interviews to a reasonable length but prevents evaluation of how the resources fit together as a whole. Several participants did, however, comment on the lack of information on PA or diet (in the diet and PA conditions, respectively) and felt that both aspects would be important to include in an intervention to promote healthy lifestyles.

The interview context, with the participant being asked to read the texts while the interviewer was in the room, was not a good reflection of real life and limits the ability to evaluate whether or not people would read all the text of their own volition. However, all participants seemed to find the texts easy to read, interesting and engaging, due both to the novelty of their content (including the facts about human evolution as well as the detailed information of physiological processes) and the writing style (active voice, everyday language). Indeed, a couple of people who commented that the pages of text looked dull at first sight went on to say that the text made them want to read on. This would suggest that, providing people can be attracted to begin reading of their own will, the texts are likely to keep them engaged enough to continue reading.

With regards to ease of understanding, the interviews elicited participants' perceptions of how easy the texts were to understand and what parts caused confusion. Through discussion in the interview, the researcher was also able to gain an idea of how accurately participants had understood the information. However, it is important to note that this study did not set out to assess the effect of the resources on participants' knowledge; for this a pre-test/post-test design would be needed with specific measures to ascertain what participants know about PA, diet and their relationship to health, before and after exposure to the resources. After further development of the resources, such a test will be necessary to evaluate their efficacy to improve understanding.

Discussion of what participants thought about the texts highlighted some words and sections that were less well understood or seemed repetitive, and so these will be changed in subsequent versions. It was also shown that additional information might be needed to reduce reactance (counter-arguing). Providing more acknowledgement of the benefits of modern life while highlighting that these benefits are often double-edged (e.g. supermarkets remove the risk associated with hunting wild animals, yet the convenience poses new risks in the form of encouraging over-consumption and inactivity) could help to reduce the counter-arguing voiced by some participants in this study, and thereby improve acceptance of the information (Byrne & Niederdeppe, 2011; Petty & Cacioppo, 1986). On the other hand, adding more evidence to the texts would increase their length and complexity, which might be off-putting if the additional information is not deemed to be necessary or relevant by an individual (Abraham, 2012a; Fitzgibbon et al., 2007). Therefore, any additional information would need to be salient and kept to a minimum.

3.4.5 Performance of narratives

Narrative accounts were composed primarily to enhance engagement and perceptions of personal relevance, while also demonstrating how some of the behaviour change advice in the other resources could be put into action. As for the expository texts, the interview context means conclusions cannot be drawn about whether people would choose to start reading the narratives of their own accord; they were explicitly asked to read them and the pages were presented without illustrations. However, the interview discussions did suggest that the narratives were highly engaging, perceived as personally relevant and evoked positive feelings in participants. They also seemed to provide a helpful model for making behaviour changes, prompting many participants to feel that the changes modelled by the characters were achievable and might be options that they could take in their own lives. These findings are in accordance with literature on narrative transportation which purports that feelings evoked when readers are transported into the narrative-world can be carried over to influence readers in the real-world (Green, 2004; Green & Brock, 2000; Thompson & Kreuter, 2014). By promoting positive feelings towards the desired behaviour changes and making them seem attainable, the narratives might help to improve motivation and perceived self-efficacy in readers.

3.4.6 Memorability

Questionnaire 2, delivered one week after the interviews, sought to explore if and what participants had thought about the resources in the intervening week. Responses indicated that the resources had been memorable and prompted further thought after the interview, however it was difficult to elicit specifically what resources, or aspects of them, were memorable, and why. Although some participants listed certain graphics or facts that had 'stayed in mind', other participants referred to general concepts or impressions that might have come from one or more of several of the resources (e.g. What has stayed in your mind? *"How our dietary practices have outpaced our evolution"*). No single resource or fact was consistently reported as staying in mind. However, even for those participants who clearly recalled particular graphics or facts, such a recollection is likely to have triggered associated ideas from the other resources. Furthermore, it is likely that different aspects of the resources would appeal to different people depending on their prior interests and the perceived relevance of the information, which in turn would impact on the ease with which they could be recalled (Petty & Cacioppo, 1986). So, although responses to Questionnaire 2 did not show key resources or elements of the resources that were important for enhancing memorability, this is perhaps less important than the finding that all respondents did think about the information during the week following the interviews.

3.4.7 Potential of the evolutionary mismatch concept

The findings suggest that the evolutionary mismatch concept could be a useful frame in which to present health information. The perceived novelty of the mismatch concept, when related to health information, seemed to help both generate and maintain participants' interest throughout viewing the resources. Interest has been defined as an emotion which functions to motivate an individual to explore and learn (Silvia, 2008). It directs attention and promotes increased cognitive effort, deeper processing of information and greater persistence in tasks (Thoman et al., 2011); as such, interest can greatly enhance an individual's acquisition of knowledge and engagement with an educational health intervention (Crutzen & Ruiter, 2015). For something to be interesting it must be perceived as novel (Crutzen & Ruiter, 2015; Silvia, 2008). The mismatch concept not only enables a new format to be used to attract attention (i.e. juxtaposing health with evolution, which was unexpected and novel to participants in this study) but also adds new information to familiar health messages, potentially helping to sustain interest and engagement with all the intervention material. This would seem to be particularly important for a self-directed health intervention, where users may not receive any external prompts or cues to read information resources, and when information is complex; interest will generate volitional motivation to learn and persistence despite increased demand on cognitive resources (Silvia, 2008; Thoman et al., 2011).

While novelty is important for generating and maintaining interest, information also needs to be believable in order for it to be accepted, which in turn will increase the likelihood of it being stored in memory and influence attitude and behaviour change (Cappella, 2006; McGuire, 1999; Petty & Cacioppo, 1986; Petty, Kasmer, Haugtvedt & Cacioppo, 1987). The familiarity of certain elements in the mismatch concept seemed to aid acceptance of the information resources. Although simple acceptance of a message might indicate that little cognitive elaboration had been employed, which would likely lead to less stable attitude change (Petty & Cacioppo, 1986; Robertson, 2008), the feelings of interest generated by the resources would encourage cognitive elaboration. Looking back at humans' recent history as part of the mismatch concept also encouraged people to reflect on their own past, promoting a feeling of personal relevance which also encourages cognitive elaboration (Petty & Cacioppo, 1986; Petty et al., 1987).

A further potential benefit of using the mismatch concept highlighted in this study is the greater depth of understanding it provides. The mismatch concept explains why certain behaviours are harmful and also why humans are prone to behave in certain ways and this seemed to provide participants with a strong rationale for healthy behaviour change. Social-cognitive theories of behaviour suggest that this could be important for motivating behaviour change since providing a meaningful rationale supports an individual's autonomy (Deci et al., 1994; Ryan & Deci, 2000) and this, in turn, encourages formation of positive attitudes towards the target behaviour and intentions to act (Chatzisarantis et al., 2007).

This study has also highlighted some potential problems with using an evolutionary mismatch frame to present health information. Some of the graphic resources compared a specific period in human history (namely the Palaeolithic 'hunter-gatherer' period) with modern day as a means of illustrating how human lifestyles have changed. For some participants, this led to reactance whereby thoughts of the relative hardship of the hunter-gatherer lifestyle, and knowledge that Palaeolithic life expectancy was low, led to the conclusion that the modern lifestyle is preferable and so changes to revert to an ancestral lifestyle would not be desirable. It is important to point out that the target of the resources produced is not a return to the lifestyle of any particular era; rather to promote small, sustainable changes in PA and diet, showing how from an evolutionary perspective these changes make sense for our health. This is in contrast to the recently popular 'Paleo Diet' movement which does advocate consuming only foods that would have been eaten by Palaeolithic people and even trying to emulate hunter-gatherer activity patterns (Cordain, 2002). Although this movement has gained many supporters, it has faced strong criticism from health professionals and academics for being too restrictive for long-term adherence (U.S. News and World Report, 2015), for being founded on speculation rather than paleontological evidence of ancestral lifestyles (Warinner, 2013; Zuk, 2013), and for neglecting the evolutionary adaptations that have shaped humans prior to and after the Palaeolithic period (Lieberman, 2013). Much like other commercialised diet and lifestyle programmes, the Paleo Diet movement now seems to be waning in popularity (Google Trends, 2016) and it will be important to distance the current project from it. In order to do this and reduce reactance to the information supporting the mismatch concept could be clarified and greater emphasis could be placed on the examples from more recent history to ensure that the resources provide a coherent and comprehensive rationale for behaviour change. This may also help to counter the negative elaboration that some participants reported concerning lactose digestion. It is worth noting, however, that the stark contrast between hunter-gatherer and modern lifestyles highlighted in some of the graphics seemed to be particularly good at generating interest and staying in participants' minds after the interviews. Retaining this aspect would thus be desirable and, from an academic perspective, inclusion of hunter-gatherers in a depiction of human evolution is important since, for the majority of history, humans have existed as hunter-gatherers.

3.4.8 Limitations

There are some factors that limit the transferability of findings from this study. The sample was self-selected and as such had a prior interest in health. It is possible, therefore, that participants found the resources more interesting and engaging than people who have little interest in health. The majority of the sample were educated to degree level or higher, which further limits the transferability of results, since less than half of UK adults hold a tertiary education-level qualification, though in younger generations the proportion is increasing (OECD, 2015). It is also interesting to note that although the sample was well educated and interested in health, there were still deficits in knowledge concerning benefits of exercise and food groups, which the resources addressed. It is also important to bear in mind that the sample were all British. In Britain, evolution is taught in schools and generally accepted. As the resources are developed in future work, it will be important to assess whether they are acceptable, interesting and understandable for audiences of lower educational attainment and different religious beliefs.

The interview set-up in which the resources were viewed may have affected their memorability. Participants knew that they would be asked to give their opinions of the resources and, after the first set of questions, would know that the researcher would also ask what message or key points they took from the resource. This is likely to have caused participants to scrutinise the resources more thoroughly than they would if simply reading/viewing them on their own, which in turn could aid retention in memory.

3.4.9 Conclusion

Overall, the findings from this study suggest that using the concept of an evolutionary mismatch to frame health information about diet and PA could help to generate and sustain interest and strengthen the perceived rationale for behaviour change. Further development of the resources will need to address the potential for reactance and negative elaboration while capitalising on the facilitating factors the mismatch concept can bring to communicating health information. This study has also provided insight into how the resources should be refined to improve their ability to achieve proximal communication goals. The next step, after the resources have been refined, will be to test whether they can effectively improve understanding and alter cognitive determinants of behaviour change, such as attitudes and intentions.

CHAPTER 4. Study 2: Testing the influence of mismatch-framed resources on the cognitive determinants of behaviour.

4.1 Introduction

Study 1 showed that using the concept of an evolutionary mismatch to frame health information about diet and PA could help to generate interest in an intervention. The mismatch concept also seemed to provide a strong rationale for behaviour change. However, these factors alone are unlikely to be sufficient to bring about volitional behaviour change: to do this, intervention materials also need to alter the cognitions that determine behaviour (Conner & Norman, 2005). Much research has sought to identify cognitive determinants of behaviour and a wide variety of theoretical models have been created to explain how these determinants inter-relate and influence behaviour (Davis, Campbell, Hildon, Hobbs & Michie, 2015). These theories can be applied in intervention design and evaluation, helping researchers to decide which behavioural determinants to target and assess (Michie et al., 2014; Michie, Johnston, Francis, Hardeman & Eccles, 2008).

The current study drew on two key theories of behaviour change to ensure that a comprehensive set of constructs were targeted: the Theory of Planned Behaviour (TPB) and Self-Determination Theory (SDT). The theory of planned behaviour (TPB. Ajzen, 1985; 2011) has often been applied in the domains of PA and healthy eating; it sets out how attitudinal, normative and behavioural control cognitions influence intentions and ultimately behaviour. More specifically, in the TPB, expectations about a behaviour's outcomes and evaluation of these outcomes (behavioural beliefs) are proposed to determine attitudes towards the behaviour; beliefs about the expectations and behaviour of salient others are proposed to determine subjective norms; and beliefs about control are proposed to determine perceived behavioural control for the behaviour. Attitudes, subjective norms and perceived behavioural control are, in turn, thought to influence behavioural intentions, which have shown good predictive strength for actual PA and dietary behaviours (Conner & Sparks, 2005; McEachan et al., 2011). Research has shown that interventions are more likely to generate meaningful behaviour change if they affect multiple cognitive determinants simultaneously (Fife-Schaw & Abraham, 2009). In the present work, if the intervention resources can effectively improve knowledge of the effects of PA and diet on health, this may conceivably influence behavioural beliefs, and in turn, attitudes towards activity and dietary behaviours (Ajzen et al., 2011). Further, the practical advice and examples of how to make behaviour changes in the resources could influence perceived controllability and self-efficacy, which together constitute the perceived behavioural control construct in the TPB (Ajzen, 2006; Conner & Sparks, 2005). The interest and engagement with the resources that the evolutionary mismatch concept seems to help generate might enhance the effects on knowledge, beliefs, attitudes, perceived behavioural control and, in turn, intentions. Thus it could be predicted that information on the effects of PA and diet on health, when framed from the perspective of an evolutionary mismatch, will lead to greater change in these cognitive determinants than if the information is not presented from a mismatch perspective. The resources do not seek to influence subjective norms; this construct has often shown relatively poor predictive power for intentions to be physically active and consume a healthy diet among adult samples (Conner & Sparks, 2005; McEachan et al., 2011).

Self-determination theory (SDT) provides a useful model for exploring the effects of evolutionary mismatch framed resources (Deci & Ryan, 1985; 2000) . A central tenet of SDT is that human motivation varies on a continuum from controlled (i.e. where a behaviour is externally regulated, for example, through punishment or monetary incentive) to autonomous (i.e. intrinsic regulation, where an individual engages in a behaviour out of interest and enjoyment). In order to bring about the adoption and maintenance of healthy behaviours, intervention designers should seek to help individuals change the quality of their motivation to a more internalised, autonomous form. Three main factors are proposed to promote the internalisation of motivation (Deci et al., 1994): presenting a choice; acknowledging the individual's feelings; and providing a meaningful rationale for the behaviour. Supporting evidence for the efficacy of these factors in promoting internalisation comes from experimental studies that manipulated, for example, the reasons provided to participants for conducting uninteresting tasks (Deci et al., 1994; Reeve et al., 2002; Vansteenkiste, Simons, Lens, Soenens & Matos, 2005). More research is needed to fully understand the features of a rationale that are necessary for promoting internalisation (i.e. what makes a rationale meaningful) and to determine the moderating effects of various environmental factors, however a recent review has highlighted the value of providing rationales to support internalisation of motivation (Vansteenkiste et al., 2018). If the evolutionary mismatch can provide individuals with a rationale for consuming a healthy diet and engaging in PA that they find meaningful, we would expect their motivation for these behaviours to become more autonomous, which in turn should increase the likelihood of them enacting these behaviours.

This study sought to investigate whether the evolutionary mismatch framed resources (developed and augmented based on feedback from Study 1) could enhance understanding of the effects of PA and diet on health, and improve cognitive determinants of these behaviours in line with the theoretical processes outlined above (see Figures 4.1 and 4.2). The resources were designed to provide more in-depth physiological information on how PA and diet affect health than is commonly provided in health promotion materials. The use of the evolutionary frame was intended to make this complex information engaging and coherent, and thus more likely to promote cognitive elaboration and bring about change in cognitive determinants of behaviour. However, the more in-depth physiological information may have provided sufficient novelty to stimulate engagement and the extra information that the evolutionary concept provided could add an extra complexity that actually detracts from the physiological information. Therefore it was thought important to examine whether providing only physiological information about how PA and diet affect health has a greater or lesser effect on knowledge and the cognitive determinants tested. Accordingly, two sets of resources were developed and tested: one using an evolutionary mismatch framework, the other containing the same physiological information and lifestyle advice, but not framed from an evolutionary perspective. The following hypotheses were set:

1. Both sets of resources would improve the following cognitive determinants of behaviour change (1A), but greater improvements would come from the evolutionary mismatch resources (1B): knowledge of effects of PA, fibre, sugar and salt on the body; autonomous motivation for PA and diet; beliefs about the importance of PA and diet for health; outcome expectancies for PA and diet; attitudes towards PA and diet; perceived controllability of PA and diet; self-efficacy for PA and diet; and intentions to be physically active and consume a healthy diet.
2. Being provided with the evolutionary rationale for behaviour change would lead to increased autonomous motivation for PA and consuming a healthy diet compared with receiving the non-evolutionary resources, which in turn would lead to improvements in intentions to be physically active and consume a healthy diet (illustrated in Figure 4.1).
3. Improvements in knowledge would lead to improvements in outcome expectations and beliefs, which would lead to improvements in attitudes towards PA and consuming a healthy diet that would in turn lead to increased intentions to be physically active and consume a healthy diet (illustrated in Figure 4.2).

4. Improvements in knowledge would lead to improvements in perceived controllability and self-efficacy of PA and diet, which in turn would lead to improvements in intentions to be physically active and consume a healthy diet (illustrated in Figure 4.2).

Figure 4.1 Process model for the effects of exposure to the evolutionary rationale for behaviour change on behavioural intention, based on SDT

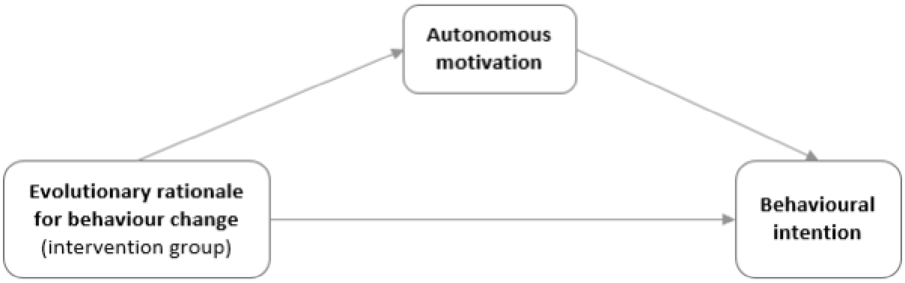
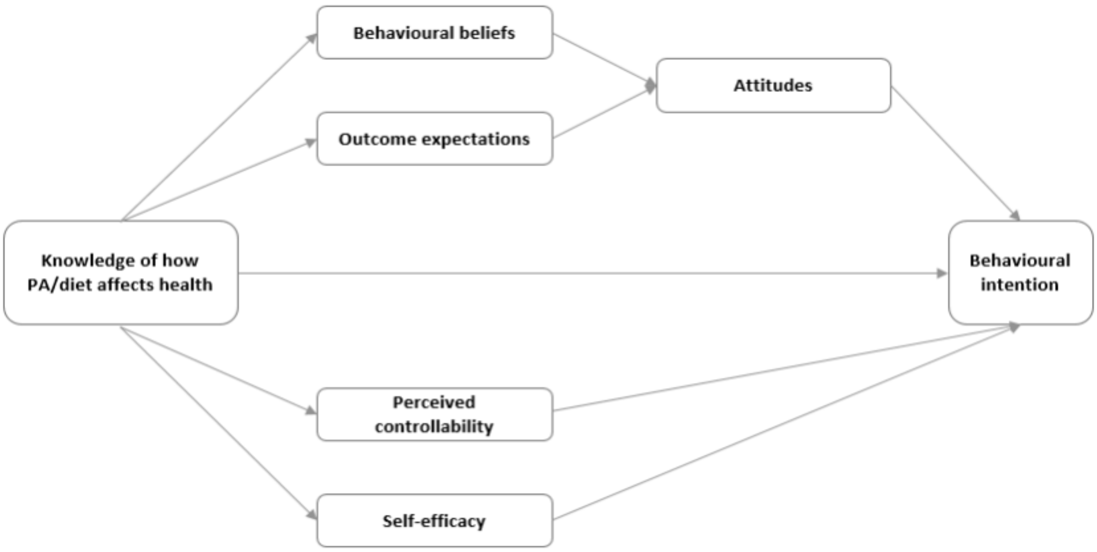


Figure 4.2 Process model for the effects of knowledge on behavioural intention, based on the TPB



This study was a further stage in the development of a behaviour change intervention, and behavioural intentions rather than actual behaviour were taken as the outcome measures as they presented a lower cost and more time-efficient variable. Several meta-analyses have found intentions for PA and healthy eating to be strong predictors of these behaviours (Conner & Sparks, 2005; McEachan et al., 2011).

4.2 Method

4.2.1 Design

A repeated measures design with two groups was taken: participants received either the evolutionary mismatch-framed resources (Evo group) or the non-evolutionary mismatch-framed resources (Non-evo group) and completed online questionnaires before and two weeks after viewing the resources. In an effort to promote the ecological validity of the study, the resources were posted to participants, who could then view them at their own pace and at times that suited them over the course of a week. After a week, participants posted the booklets back and two weeks after returning the booklets, they completed the second questionnaire. A two week delay between viewing the resources and completing the second questionnaire was employed to test the memorability of the information in the resources; this length of delay has been used in similar health information intervention studies (e.g. Atak, Gurkan & Kose, 2008; Taylor-Davis et al., 2000).

The study received ethical approval from the Research Ethics Approval Committee for Health (REACH) at the University of Bath on 22nd December 2015 (ref. EP 15/16 88).

4.2.2 Participants and recruitment

A purposive sampling approach (Braun & Clarke, 2013) was taken, aiming to recruit adults who could benefit from being more active or making changes to their diet and thus who might benefit from the resources. The following eligibility criteria were set: aged between 40 and 74 years; fluent at reading and writing in English and have access to the Internet; not meeting national recommended levels of PA (at least 150 minutes of self-reported moderate activity per week plus strengthening exercises on two or more days per week) and/or overweight (defined as having a BMI of 25kg/m^2 or higher). Screening questions were used in initial contact with participants to assess their eligibility.

A target sample size of 102 (with 51 participants in each of the two groups) was calculated to provide sufficient power ($1 - \beta = .80$) to detect a moderate effect of group ($d = .50$, $\alpha = .05$) on intention. In an attempt to recruit people from a range of backgrounds, multiple means of advertising the study were used. Advertisements were sent to local businesses and community groups, and placed in the local newspaper and on several community websites. The study was also advertised around the University of Bath. All advertisements stated brief details of what participation would involve, the eligibility criteria, that participation would be confidential, that a prize draw incentive was offered (£100, £50 or £25 in Amazon vouchers), and contact details of the researcher. The recruitment methods preclude the ability to calculate response rates, since it cannot be determined how many people saw the advertisements.

4.2.3 Materials

4.2.3.1 Health information resources

The two booklets were developed using the text and graphic resources tested in the first study: one booklet used an evolutionary mismatch framework, the other contained the same information on the proximate physiological mechanisms underlying health and the same lifestyle advice, but the evolutionary information was removed (see Appendices 4.1 and 4.2). Each booklet contained information on both PA and diet, and text that sought to address various beliefs that previous research has shown to be salient to behavioural and control beliefs. Specifically, the text emphasised that PA (Haase, Steptoe, Sallis & Wardle, 2004; Resnick, Zimmerman, Orwig, Furstenberg & Magaziner, 2001; Roberts & Marvin, 2011) and healthy eating (Anderson, Winett & Wojcik, 2007; Conner & Sparks, 2005) is achievable, could be enjoyable, would improve fitness and health and feeling fit/healthy. The feedback gained in the first study informed the development of the resources. Graphic designers were employed to help ensure the booklets looked professional and high quality. Amendments to the texts included: some re-phrasing of sentences to improve clarity; addition of some definitions (e.g. 'adaptive genes'), text to address misconceptions (namely that increased life expectancy necessarily means humans today are healthier than their ancestors) and more information on dietary fibre; and deletion of some text to reduce repetition. Short introductory paragraphs were written for each booklet, designed to be intriguing first pages that would encourage people to continue reading.

The graphic designers used the illustrative graphics and feedback from the first study as a starting point to develop graphics for the internal pages of the booklet. A visual style was decided first, which was then employed throughout both booklets, helping to ensure they appeared coherent. Based on the responses to the graphics in the first study, the style aimed to be simple, clear and attractive yet not childish or cartoon-like. Evidence-based guidelines for designing health education texts (for example, regarding spacing of text and page layouts) were followed to improve learning (Hartley, 2012; Kools, 2012). Some simple images were used to provide visual interest and break up large sections of text that may have been off-putting. These images depicted items or actions mentioned in the texts in an attempt to make them relevant rather than distracting. On the pages with the narratives, photographs of a man (John) and a woman (Cathy) were used to provide visual interest. Larger, more complex illustrations were developed to depict certain evolutionary comparisons and physiological processes. The Lists graphic style, which received the most positive responses overall in the first study, was chosen for a cover image of the evolutionary booklet. Although the 'word' Lists graphics (Apples and Hunting) were preferred by a slight majority of respondents in Study 1, this style did not seem to work as well when reduced to A5 size (the size of the printed booklets), since the text size either had to be reduced, making it harder to read, or fewer lines of text used, depleting the impression of a timeline. Therefore, the pictorial Drinks graphic was chosen but adapted to match the overall visual style by changing the photographs of drinks to digital drawings. This also addressed the main criticism of the original Drinks graphic since it enabled more colour to be used and the glasses to 'stand out' more. A grid of images of people in modern day activities, both healthy and unhealthy, was chosen for the cover of the non-evolutionary booklet; the images were in the same pictogram style that was employed throughout the booklet and deemed to be equally colourful and attractive as the evolutionary booklet cover.

The non-evolutionary booklet was, necessarily, shorter than the evolutionary booklet. In order to test the role of the evolutionary mismatch perspective in influencing cognitive determinants of behaviour change the non-evolutionary comparator could not contain any new information or go into more depth on any of the physiological/health topics. However, simply deleting all evolutionary information from the booklet meant that the text did not 'flow' very well, and so brief paragraphs were added to help link different sections of text together. The final booklets were 40 pages (Evo) and 28 pages (Non-evo) long. Throughout the development process, both booklets were read by the researcher, experts in physiology, health psychology and lay persons to check for accuracy of information, grammatical errors and clarity of graphics and to gather general feedback on the look and layout of the booklets.

In addition to the booklets, participants also received a fridge magnet depicting the cover image of the relevant booklet. The purpose of the magnet was to provide a visual reminder to participants to look at and think about the information in the booklets.

4.2.3.2 Measures

Participants completed two online questionnaires, delivered via Bristol Online Surveys: one at baseline ('Time 1' i.e. prior to seeing the booklet) and one three weeks later ('Time 2' i.e. two weeks after the booklet had been returned). The questionnaires contained a mixture of study-specific items and pre-validated measures as detailed below (see Appendices 4.3 and 4.4).

Questionnaire 1 (Time 1)

Sections 1 and 2: Demographics and current lifestyle

These sections sought to describe the baseline characteristics of the sample. Physical activity levels were assessed using items derived from the short format International Physical Activity Questionnaire (IPAQ; Craig et al., 2003). The IPAQ is a widely used measure that has been translated into over 20 different languages and has shown acceptable reliability and validity in adult samples (Craig et al., 2003). Participants were asked to report the amount of time they spent engaging in moderate and vigorous physical activities in an average week as well as the number of days in an average week, and amount of time on those days, they spent doing strengthening activities. Participants were also asked to state whether or not they felt they needed to increase their activity levels, whether they were thinking about making any changes to their activity and if so, what changes.

Current dietary habits were assessed by asking participants to indicate on 5-point scales their frequency of consumption of 12 different food products in a typical week. Response scales ranged from 'rarely or never' to 'every day'. The foods included were taken from the British Heart Foundation's (BHF) 'How Healthy is your Diet?' questionnaire, which is designed for the public to use to identify healthy and unhealthy aspects of their diet. Although some validated food frequency scales exist, they were not chosen for this study due to their length (for example, the European Prospective Investigation into Cancer and Nutrition Norfolk Food Frequency Questionnaire (EPIC-Norfolk FFQ) is 11 pages long), which would heighten the risk of response fatigue and dropping out before completion. Furthermore, the purpose of including these questions was to gain an overview of the healthiness of participants' diets and identify possible areas for improvement, rather than to gain a detailed picture of the nutrient and calorie content of their diets. Participants were also asked to rate on a scale from 0 to 10 how healthy they believed their diet to be, report whether they were on a special diet and if they were thinking of making any changes to their diet.

Section 3: Behavioural regulation

The Behavioural Regulation for Exercise Questionnaire-3 (BREQ-3; Markland & Tobin, 2004; Wilson, Rodgers, Loitz & Scime, 2006) was adapted to assess motivation for PA and healthy eating. This 24-item scale consists of six subscales relating to the six types of behavioural regulation specified on Deci and Ryan's (2000) continuum of regulation: amotivation, external regulation, introjected regulation, identified regulation, integrated regulation and intrinsic motivation. Responses are made on 5-point Likert-type scales anchored at 0 (not true for me) and 4 (very true for me) and mean scores are calculated for the items within each subscale. Following the example of Sebire, Standage and Vansteenkiste (2008), a controlled motivation factor (external and introjected regulation) and an autonomous motivation factor (identified, integrated and intrinsic regulation) were created. The BREQ is a widely used measure of behavioural regulation and has shown good validity and reliability in adult samples (Markland, 2014; Rutten et al., 2014). In the present study the BREQ was modified to assess PA rather than exercise regulation by replacing instances of 'exercise' or 'exercising' with 'physical activity', 'be active' or 'being active', as appropriate. This was to reflect the fact that 'exercise' is understood, both by lay people and physiologists, to mean structured, planned activity, whereas 'physical activity' is a broader term, incorporating both exercise and other activities that involve movement (Thompson, 2013). The distinction is important for health interventions because, although someone may not engage in any 'exercise', they might still be meeting or exceeding PA recommendations (Thompson, 2013). In the current study the resources promote increasing PA and so it was important for the questionnaires to capture cognitions about this concept rather than the more limited concept of exercise.

Section 4: Beliefs and knowledge about physical activity and diet

Beliefs about the importance of PA and diet for the maintenance of health were assessed using rating scales ranging from 1 = 'not at all important' to 10 = 'very important'. These items were based on the belief items in the International Health and Behaviour Survey (Haase et al., 2004). Four multiple choice questions were composed specifically for this study to assess knowledge about how PA and diet (specifically fibre, sugar and salt intake) affect health (see Box 4.1 for an example question). Four response statements (three for salt) were given for each question, plus two final options that 'X does not affect health' and 'X does affect health but I'm not sure how'; two options for each question (one for salt) were correct and detailed a mechanism that was explained in the health information booklets. Participants were asked to select all the statements that they agreed with or one of the last two options. The questions for PA, fibre and sugar were coded as follows: 4 = 2 correct responses, no incorrect; 3 = 1 correct, no incorrect; 2 = 2 correct + 1 incorrect/unsure; 1 = 1 correct + 1 incorrect/unsure; 0 = all other combinations. This created a scale where higher scores indicated a more correct response. The salt question was coded either correct (1) or incorrect (0).

Box 4.1 Example multiple-choice knowledge question

How does physical activity affect health? Please select **all** the statements that you agree with *or* one of the last two options.	Agree
Physical activity helps to build strong muscles which quickly remove sugar from the blood, preventing the sugar from damaging blood vessels Physical activity causes more heart muscle cells to grow, making the heart stronger. Physical activity helps to build a bigger, stronger pancreas that can produce more insulin, which is needed to lower blood sugar levels Physical activity transforms fat cells into muscle cells, making the body weigh less and so placing less strain on the heart and blood vessels Physical activity does not affect health Physical activity does affect health but I am not sure how	

Section 5: Outcome expectations

The Outcome Expectations for Exercise Scale (OEES; Resnick, 2001) was adapted to assess outcome expectations for PA. The OEES contains nine statements about outcomes (e.g. 'exercise makes me feel better physically') to which participants rate, on 5-point Likert scales, the extent to which they agree or disagree; item stems were changed from 'Exercise…' to 'Physical activity…'. The OEES has shown good reliability and validity in adult samples (Resnick et al., 2001).

The outcome expectations scale from the Food Beliefs Survey (Anderson et al., 2007; Anderson, Winett, Wojcik, Winett & Bowden, 2001) was used to assess outcome expectations for healthy eating. This scale consists of 13 statements about outcomes of eating a healthy diet: seven pertaining to positive expectations (e.g. 'If I ate a healthy diet every day I would feel healthier and happier') and six pertaining to negative expectations (e.g. 'If I ate a healthy diet every day food would not taste as good'). Participants rate their agreement on 5-point Likert scales. An additional negative expectation item was added in the current study – 'If I ate a healthy diet every day my food would cost too much'. This was deemed appropriate since cost is a commonly cited barrier to eating healthily (Roberts & Marvin, 2011).

Section 6: Attitudes, perceived controllability and intentions

Participants' attitudes, perceptions of controllability of PA and intentions towards meeting or exceeding the recommended activity levels for adults were assessed using a series of items developed in accordance with Ajzen's (2006) advice on constructing measures for variables in the theory of planned behaviour. The government's recommended activity levels were stated at the top of the page. Attitudes were assessed using five 7-point semantic differential scales (scored from 1 to 7); two relating to instrumental evaluations (e.g. unnecessary-necessary), two relating to experiential evaluations (e.g. unenjoyable-enjoyable) and one to capture the overall evaluation (bad-good) (Ajzen, 2006). Participants were asked to mark on the scales 'the extent to which you think that meeting these recommended activity levels, *for you personally*, would be/is …'. An overall measure of attitude for each participant was created by calculating the mean of the five items.

Perceived controllability of meeting the activity recommendations was assessed by two items: 'How much control do you have over whether you meet or exceed the recommended PA levels in the next month?', with responses on a 7-point scale anchored at no control and complete control; and 'Whether I do or don't meet or exceed the recommended physical activity levels in the next month is entirely up to me', with responses on a 7-point scale anchored at 'strongly disagree' and 'strongly agree'. Intention to meet the activity recommendations was also assessed by two items ('I intend to…' and 'I want to…') with responses given on a 7-point scale anchored at 'strongly disagree' and 'strongly agree'.

The same attitude, perceived controllability and intention questions were used with regards to diet, replacing the activity recommendations with the current healthy eating recommendations.

Section 7: Self-efficacy

The Barriers Self-Efficacy Scale for Exercise (BARSE; McAuley, 1992) was adapted to measure participants' perceived self-efficacy to 'regularly be physically active over the next three months'. The BARSE lists 13 different situations that have been identified as common barriers to being active (e.g. if 'the weather was very bad (hot, humid, rainy, cold)', if 'I had to do physical activity alone') and participants are asked, for each of the 13 items, to rate their confidence that they could be physically active in those situations. Responses are given on an 11-point scale anchored at 0% ('not at all confident'), 50% ('moderately confident') and 100% ('highly confident').

Self-efficacy for eating a healthy diet and shopping for healthy foods was assessed using scales developed by Pawlak and Colby (2009) in a study of Americans' perceptions towards healthy eating. The self-efficacy scale for eating a healthy diet consists of 16 items relating to a variety of circumstances and participants are asked how confident they would feel about eating healthy foods in those circumstances. There are three subscales: negative affect (e.g. ‘when you are lonely’), containing seven items; positive affect (e.g. ‘when you are happy’), containing two items[2]; and difficult/inconvenient (e.g. ‘when only unhealthy foods are readily available’), containing six items. The self-efficacy scale for shopping for healthy foods consists of seven items pertaining to different healthier food choices (e.g. ‘foods that are high in dietary fibre’) and participants are asked to rate how confident they are in their ability to select these foods. Responses to all items are given on 5-point Likert-type scales, where 1 = ‘not at all confident’ and 5 = ‘very confident’.

Questionnaire 2 (Time 2)

The second questionnaire repeated sections three to seven of the first questionnaire but replaced sections 1 and 2 (demographics and current lifestyle) with a single section on participants’ perceptions and use of the booklets (Appendix 4.4). This section contained a mixture of open- and closed-ended questions to assess, for example, how often participants had read the booklets, which parts they read more than once (if any), whether they thought about the information in the succeeding weeks, how relevant they felt the information was to them, how understandable and enjoyable they found the booklets to be, and whether they had decided to make any changes as a result of reading the booklets. The purpose of this section was to gain qualitative feedback to inform the development of the resources.

4.2.4 Procedure

Data collection took place between March and October 2016. On receiving an enquiry about participating, the researcher answered any direct questions, screened for eligibility and sent the individual an email with an information document attached (Appendix 4.5). A separate email was sent from the questionnaire platform (Bristol Online Surveys, BOS) containing a unique link to the first questionnaire. Participants were asked to read the information document and then, if they were still interested in taking part, to follow the link to the first questionnaire. The first page of the questionnaire sought participants’ consent by asking them to confirm a series of statements and they could not proceed with the questionnaire unless this was completed. At the end of the first questionnaire, participants were asked to leave

[2] In the original measure this subscale of self-efficacy for healthy eating was termed 'positive social' and consisted of two items relating to positive affect and one relating to a social situation. All three items were used in the present study but the social item was dropped as it showed poor covariance with the positive affect items and omitting it made a more reliable subscale (Cronbach's α including all three items = 0.65).

their postal address details, to which the resource packs were sent as soon as possible after the questionnaire was completed. Resource packs contained a covering letter, the allocated booklet and matching fridge magnet, and a freepost return envelope. Participants were alternately assigned to one of the two groups (i.e. the first participant received Evo resources, second participant received Non-evo resources etc.). The covering letter explained that participants were free to read the booklet when and how they liked over the course of the week, but requested that they should read the booklet at least once. Email reminders to return the booklets were sent after a week. Three weeks after a participant had received the resource pack (i.e. two weeks after they were due to return the booklet) an email link to the second questionnaire was sent to them from BOS. Reminder emails were sent if a response to the second questionnaire had not been received after a week.

4.2.5 Analysis

Data were analysed using IBM SPSS v.22 software. Mixed design (between group and repeated measures) ANOVAs were conducted to examine changes in knowledge and the cognitive determinants after exposure to the resources (Hypotheses 1A and 1B). Time (Time 1 and Time 2) was the within subjects factor and group the between subjects factor. Knowledge about salt intake, however, was measured using a binary response format (correct or incorrect) and so changes were assessed with Pearson's chi-square analysis. Separate tests were conducted for all cognitive determinant variables.

The mediation pathways of hypotheses 2, 3 and 4 were explored using the PROCESS v2.16.3 macro for SPSS (Hayes, 2013) to calculate bias-corrected 95% confidence intervals (CI) of total, direct and indirect effects, based on 5000 bootstrap iterations and including all participants. Significant mediation is established if the confidence intervals for the indirect effects do not contain 0 (i.e. both the lower and upper CIs are positive or both negative). Separate analyses were conducted for PA and diet pathways. To test hypothesis 2, intervention group (Evo vs Non-evo) formed the independent variable and autonomous motivation and intention at Time 2 were the mediator and dependent variables, respectively. To test hypotheses 3 and 4, composite scores were created for dietary knowledge (combining unit-weighted z-scores of the fibre, sugar and salt knowledge variables). Knowledge and intention at Time 2 formed the independent and dependent variables, respectively, and beliefs, outcome expectations, attitudes, perceived controllability and self-efficacy at Time 2 were mediator variables. Baseline measures of all variables were included as covariates. Diagrams illustrating the pathways are given in Figures 4.3-4.5.

Figure 4.3 Proposed mediation pathways for Hypothesis 2

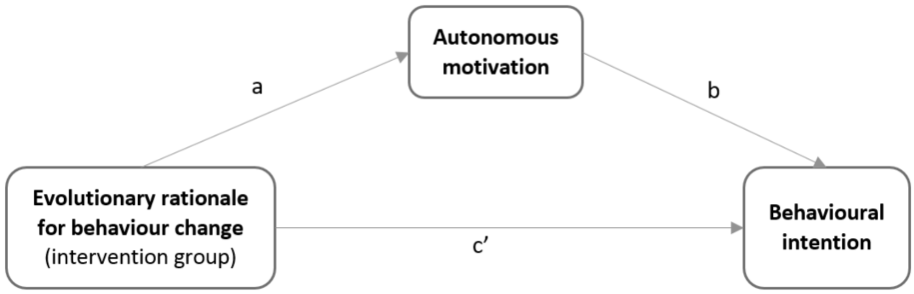


Figure 4.4 Proposed mediation pathways for Hypothesis 3

(N.B. Two separate models were tested in the analysis, one with behavioural beliefs but not outcome expectations, the other with outcome expectations but not beliefs. This was because the PROCESS macro used for analysis could not estimate models containing mediator variables in both parallel and series arrangement)

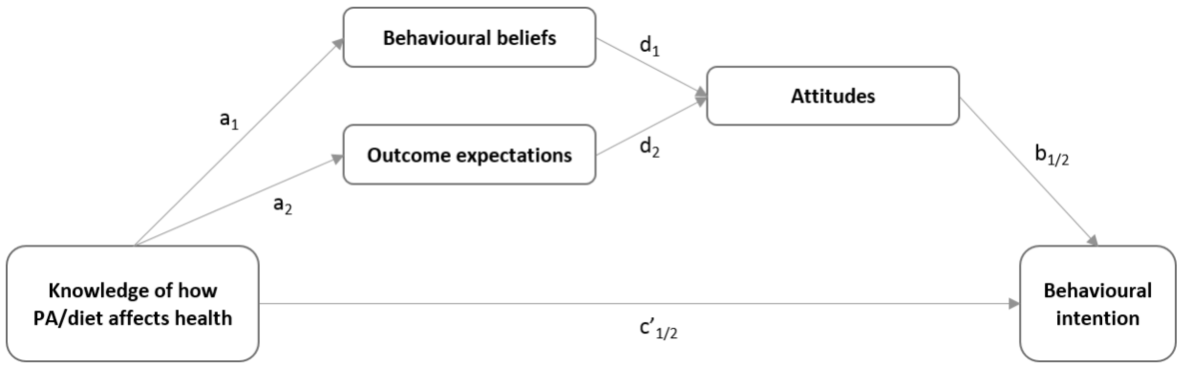
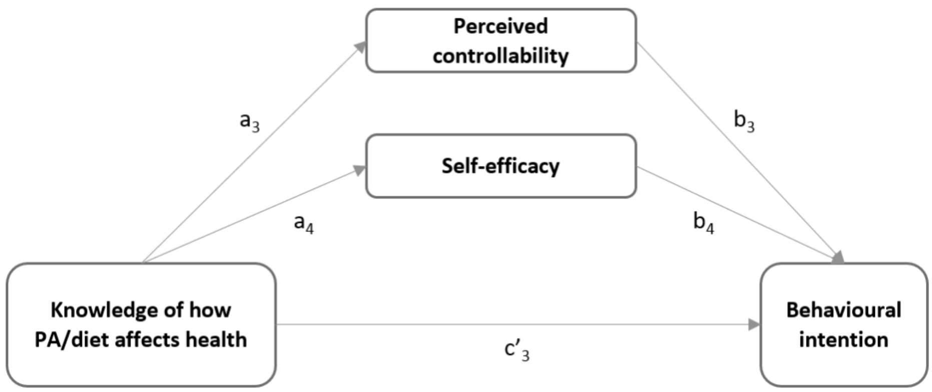


Figure 4.5 Proposed mediation pathways for Hypothesis 4



4.3 Results

One hundred and forty-one initial enquiries about participation were received, nine of these did not reach eligibility criteria and one could not access BOS. The remaining 131 people were sent the first questionnaire; 108 completed this and were sent booklets and the second questionnaire. The final sample comprised 98 people (28% male) who read the booklet and completed both questionnaires. In the final sample, ages ranged from 40 to 73 years (M = 54.9, SD = 8.0) and mean BMI at baseline was 30.4 kg/m^2 (SD 5.9). Most participants were married (60%), white (99%) and currently working (80%). Forty three percent of the sample had a university degree, which is slightly higher than the wider UK adult population (36% of 25-64 year olds had completed tertiary level education (OECD, 2018)). Those in the Evo group were significantly older than those in the Non-evo group ($t(96)=2.02$, $p<.05$) and rated the healthiness of their current diet significantly higher ($U=914.5$, $p<0.05$). Further baseline characteristics of the sample are provided in Table 4.1. Among the ten people who completed only the first questionnaire, the mean age was 49.1 years (SD = 5.8), BMI was 32.7 kg/m^2 (SD 8.7), 30% were married, all were white and in employment, and 20% had a university degree; six had been sent the Non-evo resources, four the Evo resources.

There was very little missing data since the online platform required responses to most questions before allowing participants to proceed. However, some participants did not know their body mass and, for unknown reasons, the dietary BREQ data for one participant in the second questionnaire was missing. All measures demonstrated acceptable internal consistency (see Tables 4.4 and 4.5 for Cronbach's α values).

Table 4.1 Demographic characteristics of participants, according to study condition and in total

		Evo (N = 50)	Non-evo (N = 48)	Total (N = 98)
Female	N (%)	34 (68)	37 (77)	71 (72)
Age, in years	M (SD)	56.4 (7.3)	53.2 (8.4)	54.8 (8.0)
	Range	41-73	40-73	40-73
BMI* (kg/m^2)	M (SD)	30.6 (5.7)	30.1 (6.1)	30.4 (5.9)
Marital status				
Single	N (%)	6 (12)	5 (10)	11 (11)
Stable relationship		4 (8)	10 (21)	14 (14)
Married/civil partnership		30 (60)	29 (60)	59 (60)
Divorced/separated		7 (14)	4 (8)	11 (11)
Widow/widower		3 (6)	0	3 (3)
Ethnicity				
White	N (%)	50 (100)	47 (98)	97 (99)
British Asian		0	1 (2)	1 (1)
Employment status				
Employed full/part time	N (%)	39 (78)	39 (81)	78 (80)
Student		1 (2)	0	1 (1)
Retired/unemployed		10 (20)	7 (15)	17 (17)
Prefer not to say		0	2 (4)	2 (2)
Highest educational qualification				
No formal qualification	N (%)	1 (2)	0	1 (1)
GCSE or equivalent		9 (18)	6 (33)	15 (15)
A level or equivalent		17 (34)	23 (48)	40 (41)
Bachelor's degree		8 (16)	9 (19)	17 (17)
Higher degree/advanced professional qualification		15 (30)	10 (21)	25 (26)
Perceive a need to increase personal activity levels	Yes (N)	46	45	91
	No (N)	4	3	7
Perceived healthiness of diet (0-10 scale)	M (SD)	6.22 (1.73)	5.52 (1.56)	5.88 (1.68)

*Self-report, Evo N = 49, Non-evo N = 46

4.3.1 Changes in knowledge and cognitive determinants of behavior change (Hypotheses 1A and 1B)

Knowledge

Mixed design (between group and repeated measures) ANOVAs and Pearson chi-square tests (for binary data) were conducted to investigate changes in knowledge and other cognitive determinants after exposure to the resources. Responses to the knowledge questions were first examined to see if, overall, more correct responses were achieved after exposure to the resources (Table 4.2). For the whole sample, there was improvement, of medium effect size, in knowledge of the effects of PA ($F(1,96) = 19.49$, $p < 0.001$, $d = 0.55$) and sugar intake ($F(1,96) = 18.35$, $p < 0.001$, $d = 0.51$), and improvement of small effect size in knowledge of fibre intake ($F(1,96) = 4.00$, $p < 0.05$, $d = 0.23$). Although the number of correct responses to the salt question increased (Time 1: 35; Time 2: 46), this difference was not significant. There were no group or interaction effects of meaningful size.

Table 4.2 Responses to knowledge questions

		Evo (N = 50)		Non-evo (N = 48)		Total (N = 98)	
		Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
PA	2 correct responses, no incorrect	0	11	2	10	2	21
	1 correct, no incorrect	6	3	2	2	8	5
	2 correct + 1 incorrect/unsure	5	7	8	11	13	18
	1 correct + 1 incorrect/unsure	11	7	6	6	17	13
	Incorrect combinations	28	22	30	19	58	41*
Fibre	2 correct responses, no incorrect	8	4	4	7	12	11
	1 correct, no incorrect	5	5	6	10	11	15
	2 correct + 1 incorrect/unsure	1	9	2	7	3	16
	1 correct + 1 incorrect/unsure	4	9	9	3	13	12
	Incorrect combinations	32	23	27	21	59	44**
Sugar	2 correct responses, no incorrect	2	7	0	10	2	17
	1 correct, no incorrect	6	7	10	7	16	14
	2 correct + 1 incorrect/unsure	5	5	0	6	5	11
	1 correct + 1 incorrect/unsure	6	8	6	9	12	17
	Incorrect combinations	31	23	32	16	63	39*
Salt	Correct	23	22	12	24	35	46
	Incorrect	27	28	36	24	63	52

*Significant effect of time for whole sample, p<.001
**Significant effect of time for whole sample, p<.05

The data were then analysed to compare the number of people whose knowledge improved, stayed the same or worsened after exposure to the resources (Table 4.3). More people in the Evo group demonstrated worsening knowledge of how sugar affects health (N = 10) than in the Non-evo group (N = 3; χ^2 = 4.02, $p < 0.05$, odds ratio (OR) of worsening sugar knowledge in the Evo group versus Non-evo group = 3.75, 95% CI = 0.96, 14.59), although there were no differences in the numbers who improved or retained the same level of sugar knowledge. More people in the Non-evo group demonstrated improvement in knowledge of how salt affects health (N = 19) than in the Evo group (N = 10; χ^2 (1) = 4.51, $p < 0.05$, OR improvement in the Non-evo group versus Evo group = 2.62, 95% CI = 1.06, 6.46), although there were no differences in the numbers who retained the same level of salt knowledge or worsened. This may reflect the fact that the Non-evo group had more people responding incorrectly at baseline (Evo: N = 23; Non-evo: N = 12; $t(96) = 2.21$, $p < 0.05$, $r = 0.22$).

Table 4.3 Improvement and worsening in knowledge after exposure to the resources

	Evo (N = 50)			Non-evo (N = 48)			Total (N = 98)		
	Improve	No change	Worsen	Improve	No change	Worsen	Improve	No change	Worsen
PA	23	20	7	21	19	8	44	39	15
Fibre	16	24	10	19	18	11	35	42	21
Sugar	21	19	10*	24	21	3*	45	40	13
Salt	10*	29	11	19*	22	7	29	51	18

*Significant difference between groups, p<.05

Cognitive determinants

Changes in cognitive determinants and effect sizes for the sample overall and each group are displayed in Tables 4.4 (physical activity) and 4.5 (diet). Considering the sample as a whole, the resources were associated with increases, of small effect size, in intention to be physically active (M difference (MΔ) = 0.49, $F(1,96) = 14.78$, $p < 0.05$, $d = 0.30$), intention to consume a healthy diet (MΔ= 0.26, $F(1,96) = 7.62$, $p < 0.05$, $d = 0.23$), autonomous motivation for PA (MΔ = 0.37, $F(1,96) = 37.01$, $p < 0.05$, $d = 0.37$), autonomous motivation for consuming a healthy diet (MΔ = 0.31, $F(1,96) = 22.15$, $p < 0.05$, $d = 0.34$), perceived controllability (MΔ = 0.36, $F(1,96) = 7.23$, $p < 0.05$, $d = 0.23$) and self-efficacy (MΔ = 5.78, $F(1,96) = 15.18$, $p < 0.05$, $d = 0.25$) for PA, and self-efficacy for making healthy dietary choices when feeling negative (MΔ = 0.27, $F(1,96) = 10.41$, $p < 0.05$, $d = 0.25$), positive (MΔ = 0.20, $F(1,96) = 4.94$, $p < 0.05$, $d = 0.25$) and during difficult situations (MΔ = 0.34, $F(1,96) = 25.46$, $p < 0.05$, $d = 0.38$), positive outcome expectations for PA (MΔ = 0.22, $F(1,96) = 14.95$, $p < 0.05$, $d = 0.31$) and diet (MΔ = 0.20, $F(1,96) = 13.43$, $p < 0.05$, $d = 0.33$), and beliefs about the importance of diet for health (MΔ = 0.48, $F(1,96) = 12.24$, $p < 0.05$, $d = 0.37$). Improvement was also found in negative dietary outcome expectations, which decreased over time (MΔ = -0.24, $F(1,96) = 10.56$, $p < .05$, $d = -0.29$). There were no changes in amotivation, controlled motivation and attitudes towards both PA and diet, and no change in perceived controllability of diet and self-efficacy for making healthy dietary purchases. The lack of change in attitudes and perceived controllability for diet may have been due to a ceiling effect, with baseline means of 6.03 and 6.06, respectively, on 1-7 point scales.

In general, hypothesis 1B was not supported: the evolutionary-framed resources mostly did not have greater impact on cognitive determinants than the non-evolutionary framed resources. A mixed design (between group and repeated measures) ANOVA did reveal a small interaction effect indicating that intention to consume a healthy diet from Time 1 to 2 differed between the two groups ($F(1, 96) = 3.84$, $p = 0.05$); intentions increased more over time for those in the Evo group ($M\Delta = 0.43$, $SD = 0.86$) than those in the Non-evo group ($M\Delta = 0.07$, $SD = 0.95$) and this difference between groups was of small effect size ($d = 0.40$). A mixed design ANOVA (between group and repeated measures) also revealed a small effect of group on attitude towards PA ($F(1, 96) = 6.15$, $p < 0.05$). However, there was significant heterogeneity of variances between groups at baseline, compromising the F-test and this was not improved by transforming the data. As can be seen in Table 4.4, the effect of group seems to reflect that the two groups differed in their attitudes towards PA at both time points. Those in the Evo group at first had less positive attitudes towards activity, but these improved after exposure to the resources; those in the Non-evo group had quite positive attitudes towards activity initially but these decreased after viewing the resources. Although there was no group effect for attitude towards diet, a similar pattern was found, with those receiving the evolutionary resources improving and those receiving the non-evolutionary resources deteriorating (Table 4.5). It is not possible to tell from the data whether these patterns are in fact due to the Non-evo resources having a detrimental effect on attitudes or if they reflect a measurement effect (e.g. regression to the mean or participants guessing at Time 1). However, it is notable that attitudes are the only factor for which this pattern occurred.

Table 4.4 Changes in cognitive determinants for physical activity post-exposure to the resources

Cognitive determinants – physical activity	**Cronbach's α** (Time 1)	**Evo group** (N = 50)		**Non-evo group** (N = 48)		**Effect size (d)** between groups change [1]	**All** (N = 98)		**Effect size (d)** Time 1 to Time 2
		Time 1 M (SD)	Time 2 M (SD)	Time 1 M (SD)	Time 2 M (SD)		Time 1 M (SD)	Time 2 M (SD)	
Amotivation (scale 0-4)	0.77	0.41 (0.61)	0.37 (0.71)	0.33 (0.65)	0.40 (0.58)	-0.17	0.37 (0.63)	0.38 (0.65)	0.02
Controlled motivation (scale 0-4)	0.85	1.10 (0.89)	1.27 (0.87)	1.04 (0.76)	1.10 (0.78)	0.16	1.08 (0.82)	1.19 (0.82)	0.13
Autonomous motivation (scale 0-4)	0.95	1.72 (1.06)	2.01 (0.99)	1.85 (0.90)	2.30 (0.91)	-0.25	1.79 (0.99)	2.15 (0.96)	0.37*
Beliefs about importance (scale 1-10)	-	8.16 (2.04)	8.44 (2.23)	8.48 (1.82)	8.81 (1.51)	-0.02	8.32 (1.94)	8.62 (1.91)	0.16
Outcome expectations (scale 1-5)	0.91	3.69 (0.83)	3.94 (0.61)	3.91 (0.67)	4.10 (0.56)	0.09	3.8 (0.76)	4.01 (0.59)	0.31*
Attitudes (scale 1-7)	0.82	4.86 (1.38)	5.02 (1.49)	5.59 (1.00)	5.45 (1.38)	0.24	5.22 (1.26)	5.23 (1.45)	0.01
Perceived controllability (scale 1-7)	0.76	5.40 (1.53)	5.59 (1.67)	5.21 (1.59)	5.74 (1.39)	-0.26	5.31 (1.55)	5.66 (1.53)	0.23**
Self-efficacy (scale 0-100)	0.92	36.63 (21.72)	41.71 (24.16)	38.64 (21.82)	45.16 (24.33)	-0.10	37.61 (21.68)	43.40 (24.18)	0.25*
Intention (scale 1-7)	0.79	4.47 (1.80)	4.97 (1.83)	4.98 (1.54)	5.47 (1.16)	0.01	4.72 (1.69)	5.21 (1.55)	0.30*

[1] difference between groups' change scores. Negative effect sizes indicate the Evo group's scores changed less than the Non-evo group's scores. Small effect: d = 0.2-0.49, medium effect: d = 0.5-0.79, large effect d = 0.8+.
*p<.001, **p<.01

Table 4.5 Changes in cognitive determinants for diet post-exposure to the resources

Cognitive determinants - diet	**Cronbach's α** (Pre)	**Evo group** (N = 50)		**Non-evo group** (N = 48)		**Effect size (d)** between groups change [1]	**All** (N = 98)		**Effect size (d)** Time 1 to Time 2
		Time 1 M (SD)	Time 2 M (SD)	Time 1 M (SD)	Time 2 M (SD)		Time 1 M (SD)	Time 2 M (SD)	
Amotivation (scale 0-4)[23]	0.60	0.19 (0.35)	0.17 (0.47)	0.21 (0.35)	0.22 (0.40)	-0.07	0.2 (0.35)	0.19 (0.44)	- 0.03
Controlled motivation (scale 0-4)[3]	0.82	1.27 (0.86)	1.43 (0.94)	1.14 (0.68)	1.16 (0.69)	0.20	1.21 (0.78)	1.3 (0.84)	0.11
Autonomous motivation (scale 0-4)[3]	0.94	2.24 (1.00)	2.61 (0.89)	2.22 (0.87)	2.45 (0.83)	0.20	2.23 (0.94)	2.54 (0.86)	0.34*
Beliefs about importance (scale 1-10)	-	8.84 (1.50)	9.34 (0.96)	8.77 (1.53)	9.23 (1.06)	0.03	8.81 (1.51)	9.29 (1.01)	0.37*
Outcome expectations – positive (scale 1-5)	0.92	4.12 (0.76)	4.29 (0.58)	4.09 (0.60)	4.33 (0.48)	-0.13	4.11 (0.68)	4.31 (0.53)	0.33*
Outcome expectations – negative (scale 1-5)	0.91	2.52 (1.03)	2.21 (0.83)	2.49 (0.83)	2.32 (0.80)	-0.18	2.51 (0.93)	2.26 (0.81)	-0.29
Attitudes (scale 1-7)	0.92	5.88 (1.32)	6.20 (1.14)	6.20 (1.01)	5.98 (1.33)	0.38	6.03 (1.18)	6.09 (1.23)	0.05
Perceived controllability (scale 1-7)	0.86	6.22 (1.10)	5.90 (1.46)	6.29 (0.95)	5.97 (1.37)	-0.00	6.06 (1.29)	6.13 (1.18)	0.06
Self-efficacy – negative affect (scale 1-5)	0.91	2.93 (1.02)	3.07 (1.02)	2.71 (1.00)	3.10 (1.04)	-0.29	2.82 (1.01)	3.08 (1.03)	0.25**
Self-efficacy – positive affect (scale 1-5)	0.97	4.38 (0.97)	4.58 (0.77)	4.25 (0.84)	4.46 (0.70)	-0.01	4.32 (0.91)	4.52 (0.73)	0.24***
Self-efficacy – difficult situations (scale 1-5)	0.84	3.40 (0.94)	3.73 (0.77)	3.25 (0.88)	3.60 (0.86)	-0.03	3.33 (0.91)	3.66 (0.81)	0.38*
Self-efficacy – purchasing (scale 1-5)	0.83	3.89 (0.88)	4.16 (0.71)	3.98 (0.86)	4.03 (0.88)	0.25	3.93 (0.87)	4.09 (0.80)	0.19
Intention (scale 1-7)	0.75	5.89 (1.26)	6.32 (1.00)	5.86 (1.08)	5.94 (0.92)	0.40°	5.88 (1.17)	6.13 (0.98)	0.23**

[1] difference between groups' change scores. Negative effect sizes indicate the Evo group's scores changed less than the Non-evo group's scores. Small effect: d = 0.2-0.49, medium effect: d = 0.5-0.79, large effect d = 0.8+. [2]Amotivation subscale showed poor reliability at baseline but this improved at post exposure (0.82)
[3]N = 97 (Evo N = 50, Non-evo N = 47)
*p<.001, **p<.01, ***p<.05, °p=.05

4.3.2 Process analyses (Hypotheses 2-4)

Results from the mediation process analyses are given in Tables 4.6 (PA-related mediation models) and 4.7 (diet-related mediation models). Exposure to the evolutionary rationale for behaviour change did not have a direct effect on intentions to be physically active, nor was there an indirect effect through changes in autonomous motivation for PA. Greater autonomous motivation for PA was associated with higher intention to be active ($b = 0.54$, 95% CI = 0.14; 0.95) but increasing autonomous motivation could not be attributed to exposure to the evolutionary rationale. The evolutionary rationale did, though, have a direct influence on intentions to consume a healthy diet: exposure to the evolutionary information was associated with greater intention to consume a healthy diet ($c' = 0.30$, 95% CI = 0.03; 0.58). However, this effect was not mediated through autonomous motivation for healthy eating.

Knowledge of the effects of PA on health did not have a direct effect on intentions to be physically active in any of the models tested. However, knowledge was found to indirectly affect intentions through self-efficacy for PA ($a_4b_4=0.08$, 95% CI=0.01; 0.19): participants showing a greater knowledge of the health effects of PA had higher self-efficacy for activity ($a_4 = 2.05$, 95% CI = 0.15; 3.94), which in turn predicted greater intention to be active ($b_4 = 0.04$, 95% CI = 0.03; 0.05). Belief about the importance of PA for health was associated with attitudes to PA in the predicted, positive direction, i.e. the more important a person believed activity to be for health, the more positive their attitudes were to PA ($d_1 = 0.16$, 95% CI = 0.02; 0.31). More positive attitudes were, in both models containing this variable, associated with greater intention to be active ($b_1 = 0.31$, 95% CI = 0.12; 0.50; $b_2 = 0.29$, 95% CI = 0.10; 0.48).

Knowledge of the effects of diet on health did not have significant direct or indirect effects on intentions to consume a healthy diet in any of the models tested. Attitudes towards consuming a healthy diet were found to influence intentions in both models containing attitudes: more positive attitudes predicted greater intentions to consume a healthy diet ($b_1 = 0.19$, 95% CI =0.06; 0.33; $b_2= 0.14$, 95% CI = 0.01; 0.27). However, unlike for PA, neither beliefs nor outcome expectations influenced attitudes. Self-efficacy for consuming a healthy diet was also found to predict intentions in the expected direction: participants reporting higher self-efficacy also showed greater intentions to consume a healthy diet ($b_4 = 0.52$, 95% CI = 0.20; 0.84).

Table 4.6 Physical activity mediation model effects

Model	Coefficient	S.E.	p	Bootstrap 95% CI
Rationale to Intention via Autonomous motivation				
Total effect	-0.18	0.23	0.44	(-0.63; 0.28)
Direct effect (c' pathway)	-0.10	0.22	0.67	(-0.54; 0.35)
Indirect (mediated) effect	-0.08	0.07	-	(-0.27; 0.02)
a pathway	-0.15	0.11	0.18	(-0.38; 0.07)
b pathway	0.54	0.20	0.01	(0.14; 0.95)
Model R^2 (p)		0.49 (<0.001)		
Knowledge to Intention via Beliefs and Attitudes				
Total effect	0.05	0.07	0.50	(-0.10; 0.20)
Direct effect (c'_1)	0.01	0.07	0.85	(-0.13; 0.16)
Indirect effect	<0.01	0.01	-	(-0.01; 0.01)
a_1 pathway	0.01	0.11	0.94	(-0.21; 0.23)
d_1 pathway	0.16	0.07	0.03	(0.02; 0.31)
b_1 pathway	0.31	0.10	<0.01	(0.12; 0.50)
Model R^2 (p)		0.52 (<0.001)		
Knowledge to Intention via Outcome expectations and Attitudes				
Total effect	0.04	0.07	0.56	(-0.10; 0.19)
Direct effect (c'_2)	-0.001	0.07	0.99	(-0.14; 0.14)
Indirect effect	<0.01	0.01	-	(-0.003; 0.02)
a_2 pathway	0.02	0.03	0.41	(-0.03; 0.08)
d_2 pathway	0.46	0.28	0.11	(-0.10; 1.02)
b_2 pathway	0.29	0.10	<0.01	(0.10; 0.48)
Model R^2 (p)		0.51 (<0.001)		
Knowledge to Intention via Perceived controllability or Self-efficacy				
Total effect	0.05	0.08	0.55	(-0.11; 0.20)
Direct effect (c'_3)	-0.04	0.07	0.58	(-0.18; 0.10)
Indirect effect (Perceived controllability)	0.003	0.01	-	(-0.02; 0.04)
a_3 pathway	0.13	0.08	0.11	(-0.03; 0.29)

b_3 pathway	0.03	0.09	0.74	(-0.15; 0.21)
Indirect effect (Self-efficacy)	0.08	0.05	-	(0.01; 0.19)
a_4 pathway	2.05	0.95	0.03	(0.15; 3.94)
b_4 pathway	0.04	0.01	<0.01	(0.03; 0.05)
Model R^2 (p)		0.49 (<0.001)		

Regression coefficients are in unstandardized form. The pathways (a, b, c and d) refer to those illustrated in the mediation model diagrams (Figures 4.3 – 4.5).

Table 4.7 Diet mediation model effects

Model	Coefficient	S.E.	p	Bootstrap 95% CI
Rationale to Intention via Autonomous motivation				
Total effect	0.38	0.15	0.01	(0.08; 0.67)
Direct effect (c' pathway)	0.30	0.14	0.03	(0.03; 0.58)
Indirect (mediated) effect	0.07	0.06	-	(-0.02; 0.23)
a pathway	0.15	0.12	0.21	(-0.09; 0.38)
b pathway	0.51	0.12	<0.01	(0.26; 0.75)
Model R^2 (p)		0.46 (<0.001)		
Knowledge to Intention via Beliefs and Attitudes				
Total effect	-0.003	0.03	0.93	(-0.07; 0.06)
Direct effect (c'_1)	-0.002	0.03	0.96	(-0.07; 0.06)
Indirect effect	<0.01	<0.01	-	(-0.0004; 0.01)
a_1 pathway	0.04	0.04	0.32	(-0.04; 0.12)
d_1 pathway	0.21	0.14	0.13	(-0.06; 0.47)
b_1 pathway	0.19	0.07	<0.01	(0.06; 0.33)
Model R^2 (p)		0.43 (<0.001)		
Knowledge to Intention via Outcome expectations and Attitudes				
Total effect	-0.004	0.03	0.90	(-0.07; 0.06)
Direct effect (c'_2)	-0.01	0.03	0.82	(-0.07; 0.06)
Indirect effect	<0.01	<0.01	-	(-0.001; 0.01)
a_2 pathway	0.01	0.02	0.53	(-0.02; 0.04)
d_2 pathway	0.56	0.32	0.09	(-0.08; 1.21)
b_2 pathway	0.14	0.07	0.03	(0.01; 0.27)
Model R^2 (p)		0.45 (<0.001)		
Knowledge to Intention via Perceived controllability or Self-efficacy				
Total effect	0.01	0.03	0.87	(-0.06; 0.07)
Direct effect (c'_3)	-0.01	0.03	0.85	(-0.07; 0.06)
Indirect effect (Perceived controllability)	<0.01	<0.01	-	(-0.01; 0.01)

a_3 pathway	-0.02	0.03	0.66	(-0.08; 0.05)
b_3 pathway	<0.01	0.10	0.99	(-0.19; 0.20)
Indirect effect (Self-efficacy)	0.01	0.01	-	(-0.05; 0.04)
a_4 pathway	0.02	0.02	0.29	(-0.02; 0.06)
b_4 pathway	0.52	0.16	<0.01	(0.20; 0.84)
Model R^2 (p)		0.47 (<0.001)		

4.3.3 Perceptions and use of resources

There were no significant differences between the groups' use of the resources or their perceptions of relevance, comprehensiveness, credibility or enjoyment. Only one person reported not having read their entire booklet (instead reading only certain parts), with 38% reporting having read their booklets several times. The vast majority of the sample (97%) thought about the information in the resources after reading the booklets and only 3% were not prompted to think about their own lifestyles. Ratings of how understandable, believable and enjoyable the resources were to read were very positive, with median scores of 7, 7, and 6, respectively (on 1-7 scales). Several participants commented that although they found the physiological information understandable while reading the booklets, they found it difficult to recall and would have liked to have the resources to refer to again. When asked if there was anything in the resources they did not like, three people reported finding parts patronising, while four people found parts too complex and 'academic'. About half the sample displayed their magnets to prompt them and, while some people reported finding them a useful reminder, about the same number of people reported that they weren't helpful and went unnoticed. The majority of the sample (93%) reported having thought about making lifestyle changes as a result of reading the resources and 76% reported having actually made changes (35 in the Evo group, 39 in the Non-evo group). Of those who had made changes, the majority (N = 41) had changed both their activity and diet, with a further 19 people making changes only to their diet and 14 only to their activity. The most commonly reported change for activity was increasing walking and for diet, reducing sugar intake.

4.4 Discussion

This study sought to investigate whether framing complex health information in terms of an evolutionary mismatch could enhance understanding of the effects of PA and diet on health and improve cognitive determinants of these behaviours more than providing this information without the mismatch frame. In addition, the study tested several theoretical process models based on SDT and the TPB in order to better understand how the information resources might influence behaviour. Overall, both sets of resources led to improvements in knowledge of the effects of PA and diet on the body: more correct responses and fewer incorrect responses were given after viewing the resources. However, the evolutionary mismatch framed resources did not lead to greater improvements than the non-evolutionary framed resources. Between 30 and 46% of the sample showed improvement in the various knowledge domains. However, it is difficult to compare these effects with those of other health education interventions because assessment measures tend to be study-specific and mean scores are reported, rather than numbers that have improved or worsened. The results seem comparable, though, with those of Taylor-Davis and colleagues (2000) who found a decrease in incorrect responses to a nutrition knowledge test following a newsletter intervention (% incorrect at baseline ~60, % incorrect post-intervention ~40).

Both sets of resources were successful at generating changes in most of the targeted cognitions, which supports Hypothesis 1A. Significant improvements were found in intentions, autonomous motivation, perceived controllability (for PA), self-efficacy, outcome expectations and beliefs (for diet). These changes had small but meaningful effect sizes which, considering the short duration and entirely self-directed nature of delivery, is promising for further development of the resources into a longer, more structured intervention. However, there were no significant changes in beliefs about the importance of PA, or perceived controllability and negative outcome expectations of diet and self-efficacy for purchasing healthy foods. All these factors improved slightly in the expected directions and it is possible that the results reflect a ceiling effect as baseline scores were fairly high. There were few differences between the groups, providing little support for Hypothesis 1B, but the differences that there were indicated a slight advantage in using the evolutionary resources. The evolutionary resources were associated with greater increases in intentions to consume a healthy diet and led to improvement in attitudes towards physical activity and diet, while the non-evolutionary resources were associated with deteriorating attitudes. Perhaps more importantly, framing health information from the perspective of an evolutionary mismatch did not detract from the main messages nor diminish the impact on behavioural determinants.

Hypothesis 2 was also only partially supported: although greater autonomous motivation was associated with increased intentions, the evolutionary resources did not increase autonomous motivation more than the non-evolutionary resources. Hypothesis 2 was based on the premise within SDT that having a meaningful rationale to behave in a certain way will increase autonomous motivation for that behaviour (Deci et al., 1994). The results suggest that the mismatch concept did not provide a more meaningful rationale than the physiological information alone but that both sets of resources did promote internalisation of motivation. Both resources provided more detailed information about the effects of activity and diet on health than is available in most educational health promotion materials and it may be that the greater detail would be beneficial for promoting autonomous motivation and intentions to change. However, this study did not include a comparison group to test existing public health materials and so it cannot be concluded that these do not provide a meaningful rationale for behaviour change and promote autonomous motivation.

The results provide limited support for Hypotheses 3 and 4. These hypotheses were based on the TPB, which proposes that beliefs determine attitudes and behavioural control cognitions, which in turn directly predict intentions. In this model, knowledge is thought to influence beliefs. For both PA and diet, attitudes and self-efficacy (but not perceived controllability) predicted intentions. However, only knowledge and beliefs of PA played predictive roles, influencing self-efficacy and attitudes, respectively. The low influence of knowledge could suggest that the knowledge assessed (i.e. *how* PA and diet impact on health) is not the most salient in determining the beliefs that predict behaviour. Previous studies have found that neither the amount nor the accuracy of information a person possesses necessarily predicts their beliefs (Ajzen et al., 2011); beliefs may be biased or unrepresentative of certain information a person holds. Ajzen and colleagues (2011) proposed that the information that is most likely to affect behavioural beliefs will have direct implications for behaviour and be at a personal level (e.g. PA will help *my* body build strong muscles, which will quickly remove sugar from *my* blood). Although the questions assessing knowledge did have direct behavioural implications, they were phrased in a general (non-personal) way to reflect the text in the resources. Questions relating to the individual may have shown a stronger relationship with behavioural beliefs and other cognitive determinants. It should also be noted that participants completed the second questionnaire two weeks after viewing the resources, thus the assessment was also a test of their memory.

Beliefs and attitudes are also likely to be influenced by other factors, including previously learned (potentially inaccurate) information, habits, personality traits and cultural values (Fishbein & Yzer, 2003). It might take some time for recently learned information to influence beliefs, attitudes, perceived control, intentions and behaviour; Miller and colleagues (2011) have proposed that for new behavioural knowledge to be accepted and affect attitudes and behaviour in the long-term, a practise period (where the information is acted upon) is required in which the new information is consolidated with previous information and associated procedural knowledge. The delay of two weeks between viewing the resources and completing the second questionnaire may not have been long enough for the newly acquired information on the health effects of activity and diet to be consolidated. The observed changes in the cognitive determinants may therefore have come from other information in the resources, such as the practical advice. For both PA and diet, attitudes and self-efficacy predicted intentions, which is in line with previous reviews of TPB-based prospective studies (Hagger, Chatzisarantis & Biddle, 2002; McEachan et al., 2011) although the associations in this short-term study were weaker.

4.4.1 Strengths and limitations

This study had a high retention rate (74.8% of those who received the initial questionnaire) and the sample included a wide range of ages. It was also fairly representative of the general population in terms of educational attainment (OECD, 2018). However, the ten people who completed only the first questionnaire tended to be younger, heavier and less highly educated, which might indicate that the resources are not as engaging or effective for this audience. A growth mixture modelling analysis of data pooled from two large weight-loss interventions was recently conducted to identify different trajectories in body mass change; this study found that younger participants with higher baseline BMIs were less likely to achieve rapid or continuing loss in body mass, suggesting that different intervention strategies might be necessary for people of different ages and initial body masses (Batterham, Tapsell & Charlton, 2016). It is also important to note that the sample was British and as such likely to be aware of and accepting of evolutionary theory. The evolutionary mismatch-based resources may not be accepted or understood by people of different cultures where evolution is not taught or accepted.

4.4.2 Implications for further development of the resources

One potential threat to using the additional illustrations and information in the evolutionary materials is that, while they may be more attention-grabbing, they may also draw attention away from the central health message. There was little difference between the effects of the evolutionary mismatch-based resources and those of the non-evolutionary ones, suggesting that the mismatch concept is not distracting or detrimental to conveying health messages (Houts et al., 2006; Silvia, 2006). Furthermore, the significantly greater improvement in intentions to eat healthily and the positive (as opposed to negative) impact on attitudes found with the evolutionary resources indicates that, of the two sets of resources tested here, the mismatch-based ones would be better for taking forward in an intervention. The findings indicate that future iterations of the resources may benefit from targeting perceptions of controllability of diet and self-efficacy in choosing healthier foods to buy. This could be done by providing examples (e.g. in the narratives) of how barriers can be overcome to increase control over diet, and including more information about food types and what to look for on food labels.

Although many people reported having made some changes to their lifestyles as a result of reading the booklets, the cognitive changes achieved had small effect sizes. Larger effects in cognitive determinants are generally required to bring about maintained behaviour change (Fife-Schaw & Abraham, 2009). Providing resources for a longer period of time, enabling people to refer to them as needed to reinforce the messages and enhance conceptual integration and learning (Miller et al., 2011), could help increase change in cognitions. In addition, evidence from several large systematic reviews of interventions to promote healthy eating and PA also suggests that incorporating practical techniques that build on motivation and intention is more likely to lead to effective behaviour change and improved health (Davies, Spence, Vandelanotte, Caperchione & Mummery, 2012; Dombrowski et al., 2012; Greaves et al., 2011). Specifically, asking individuals to set behavioural and outcome goals and monitor their behaviour have been strongly associated with increased effectiveness. The resources tested so far show potential for increasing motivation and intention, but in creating a more comprehensive intervention, practical post-intention techniques should be added. On the other hand, low intensity (and therefore relatively low cost) interventions that achieve effects of small size can still have large public health impact as they have the potential to reach many more people than higher intensity, face-to-face interventions (Vandelanotte et al., 2016). The resources tested in this study could easily be distributed on a larger scale (e.g. via primary care providers) and the findings suggest that they could have meaningful impact on the population's health.

4.4.3 Conclusion

This study has shown that providing physiological information about the effects of diet and PA on health can promote meaningful change in known cognitive determinants of behaviour change. Using the concept of an evolutionary mismatch to frame the physiological information does not seem to distract from the health messages and might help to increase change in attitudes and intentions towards healthy eating and PA. The proposed process models were only partially supported, showing physiological knowledge and behavioural beliefs to have less influence on motivation, attitudes, self-efficacy and intentions than anticipated. It might be that other factors, besides those measured in this study, mediated or influenced the observed effects. Providing the information in a longer-term intervention might help to strengthen its effects and enable exploration of the cognitive processes at work in more detail. This study has also highlighted ways in which the resources can be improved and what additional techniques might need to be added when developing them into an intervention.

CHAPTER 5. Study 3: Evolife – A randomised controlled trial of an evolutionary mismatch-framed intervention to promote physical activity and healthy eating

5.1 Introduction

In Study 2 it was found that the health information resources about PA and healthy eating, framed from the perspective of an evolutionary mismatch, brought about meaningful improvements in several cognitive determinants of behaviour change. Furthermore, there were some indications that the mismatch frame provided some advantage over simply providing physiological information; greater improvements in intentions and attitudes towards healthy eating and PA were found with the mismatch-framed resources. The changes in cognition seen in Study 2 tended to be small; previous research has, however, concluded that medium to large change in cognitive determinants, such as intentions, are required to bring about even small changes in behaviour (Fife-Schaw & Abraham, 2009; McEachan et al., 2011). The small effects found in Study 2 were likely partly due to the short-term exposure to the resources. Another factor that may have limited the effectiveness of the resources is the passive nature of content delivery: the booklets were not interactive, requiring input from the user and providing feedback or further information in return. Interactivity in interventions has been shown to increase learning and engagement (Short, Rebar, Plotnikoff & Vandelanotte, 2015), which in turn helps promote behaviour change (Davies et al., 2012; Webb et al., 2010). The booklets also provided generic information which, although a low cost strategy, may not be as effective as providing some degree of personalised advice (Kreuter, Strecher & Glassman, 1999). Personalising intervention content is likely to increase the user's attention, make the content seem more relevant to the user and thus promote deeper cognitive processing (Brug & Oenema, 2012).

The study presented in this chapter sought to test an Internet-delivered (or 'online') intervention that was developed from the mismatch resources tested in Study 2. Using the Internet to deliver health interventions has great potential to reach large audiences (Rogers, Lemmen, Kramer, Mann & Chopra, 2017; Short et al., 2015). The Internet is particularly well-placed to deliver self-directed interventions (i.e. those requiring no professional contact or no contact beyond an introductory session; Tang, Abraham, Greaves & Nikolaou, 2016), which if effective present a very low-cost means of reaching public health aims of promoting healthy individual lifestyle change (National Institute for Health and Clinical Excellence, 2007). Online interventions can quite easily be personalised and interactive; for example, algorithms can be built into the site so that input from the user will determine what information is displayed (Brug & Oenema, 2012). Developing the mismatch resources into an online intervention thus presented an opportunity to enhance engagement with the informational content and increase the likelihood of effecting change in cognition and behaviour.

The effectiveness of online behaviour change interventions, as with other interventions, is mediated both by factors related to user engagement (e.g. whether prompts/reminders to use the intervention site are given, the extent to which the content is personalised) and factors related to behaviour change (e.g. the number and type of behaviour change techniques included; Kohl, Crutzen & de Vries, 2013; Short et al., 2015). Most research to date has focused on behaviour change factors, particularly trying to establish which psychosocial determinants of behaviour can and should be targeted in online interventions. Relatively little research has investigated how to promote engagement; however, experimental studies by Crutzen and colleagues (2014) demonstrated that stimulating users' interest in an intervention website positively predicted both intention to visit the website and the number of pages viewed when on the website. In Study 1, the evolutionary mismatch concept was found to stimulate participants' interest, thus using the mismatch concept to frame information in an intervention website could help to promote user engagement with the website content. Other factors that are theorised to be associated with increased engagement in an online intervention include the perceived relevance of the content, the aesthetic appeal and usability of the site, and the presence of interactive features (O'Brien & Toms, 2008; Short et al., 2015). These factors can all influence the user's affect, promoting a positive experience that increases the likelihood of sustained engagement.

Online interventions can incorporate both active behaviour change techniques (i.e. those requiring input from the user) and passive techniques (i.e. those where the user simply receives, say, information from the provider. Michie et al., 2013; Tang, Abraham, Stamp & Greaves, 2015). Many behaviour change techniques have been associated with promoting PA and healthy eating behaviours and these have shown variable effectiveness in different interventions with different target audiences. Self-monitoring of behaviour is a technique that has shown particularly good efficacy in dietary and PA interventions (Dombrowski et al., 2012; Greaves et al., 2011; Michie et al., 2009). This technique involves providing the user with a means of measuring and recording their behaviour (Michie et al., 2013). A particularly effective form of self-monitoring for PA is to provide a pedometer and some form of diary for the individual to count and record their steps each day, usually working towards a step goal

(Greaves et al., 2011). Website-based interventions can provide an interactive system for users to record their step counts; the user-inputted step data can then be displayed graphically to present attractive feedback of the user's progress. A systematic review of intervention techniques by Michie and colleagues (2009) found that self-monitoring was most effective when used in combination with at least one of the following other techniques: goal setting, action planning in relation to the goals, feedback on performance and review of performance. In a meta-analysis focusing on Internet interventions, modelling of the desired behaviour, goal setting, action planning, coping planning and provision of feedback on performance were all associated with increased effectiveness (Webb et al., 2010).

Three of the most effective behaviour change techniques - action planning, coping planning and self-monitoring - are self-regulatory skills that help translate motivation and self-efficacy for a (new) behaviour into action (Dishman et al., 2005; Nurmi et al., 2016; Sniehotta, Scholz & Schwarzer, 2005; Teixeira et al., 2011). It is well understood that simply being motivated or having high self-efficacy for a behaviour does not always lead to enactment - many psychological and physical obstacles can stand in the way (Orbell & Sheeran, 1998). Self-regulation refers to an individual's efforts to avoid habitual or innate responses to situational cues by controlling their thoughts, feelings and task performances, and thus overcome obstacles to enacting desired behaviours (Baumeister et al., 2006; Sniehotta, Schwarzer, et al., 2005). Action planning (synonymous with implementation intentions) involves specifying when, where and how to act, therefore linking environmental cues to goal behaviours (Gollwitzer, 1999; Sniehotta, Schwarzer, et al., 2005). Coping planning is a related technique that first involves identifying perceived or experienced barriers to enacting a goal behaviour and then setting plans of how to avoid or overcome these obstacles. This technique is thought to work by forming mental links between anticipated risk situations and coping responses, thus making the response more likely to be remembered should the risk be encountered (Sniehotta, Schwarzer, et al., 2005). Self-monitoring of behaviour ensures the person pays attention to their behaviour and enables them to evaluate their progress, which in turn facilitates self-reinforcement of progress made (Burke, Wang & Sevick, 2011; Laitner, Minski & Perri, 2016). By including both techniques to facilitate self-regulatory skills and techniques to promote autonomous motivation and self-efficacy, an intervention can influence the two key phases (motivational and implemental) of the behaviour change process (Nurmi et al., 2016; Teixeira et al., 2015). The evolutionary mismatch-based resources tested in Study 2 brought about meaningful increases in autonomous motivation and self-efficacy for PA and healthy eating. Their effect on these cognitions may further be enhanced by increasing engagement, as discussed above, but by combining them with self-regulatory techniques, the resulting intervention would be more likely to bring about behaviour change.

Eliciting social support for behavioural change was additionally found to enhance weight loss in a systematic review of reviews of dietary and PA interventions conducted by Greaves and colleagues (2011). Social support can be emotional (e.g. providing praise, empathy or encouragement) or practical (e.g. asking colleagues not to offer biscuits and cakes in the workplace, or asking a partner to remind you to go to a gym class. Michie et al., 2013). Unlike self-regulatory techniques, social support is not thought to mediate the effect of autonomous motivation or self-efficacy, rather it represents an additional socio-environmental factor that affects behaviour (Bandura, 2004; Barrera , Strycker, MacKinnon & Toobert, 2008). Behaviour change interventions can teach users ways of mobilising support from their existing social networks (Barrera et al., 2008). In developing the evolutionary resources into an online intervention, information can be added on eliciting social support to further promote behaviour change.

If a health intervention is successful in promoting behaviour change, with consistent repetition of the new behaviour it would further be expected that new habits would form, whereby the new or goal behaviour would be performed automatically in response to learned situational cues (Gardner, 2015). This would decrease the need for conscious self-regulatory techniques and social support. The length of time it takes to form new habits is highly variable between individuals and behaviours; for example, in a study where participants were asked to choose and carry out daily a new dietary or PA behaviour it was found to take between 18 and 254 days before the new behaviours became habitual (Lally, van Jaarsveld, Potts & Wardle, 2010). This would suggest that interventions lasting as little as three weeks could instil new habits in some participants, although the average length to habit formation that Lally and colleagues (2012) found was 66 days, which implies that longer interventions or those that have lasting effects would be more likely to bring about new habit formation.

This study sought to test an online intervention developed from the evolutionary mismatch resources to also include active behaviour change techniques that have shown good efficacy in previous research (see section 5.2.6 for details of techniques included). The intervention was primarily intended to promote increases in physical activity levels and reductions in energy intake among overweight and obese men and women aged 35 to 74 years. This population is at increased risk of developing type 2 diabetes (T2DM) and cardiovascular disease (CVD) and the need for effective interventions to improve modifiable lifestyle behaviours among this population has been highlighted (National Institute for Health and Care Excellence, 2014b; National Institute for Health and Clinical Excellence, 2010, 2012). The intervention was designed to impact behaviour by influencing various cognitive determinants and self-regulatory factors associated with behaviour change (set out in the objectives below).

5.1.1 Objectives

The primary objective of this study was to assess the effectiveness of an evolutionary-framed, self-directed intervention designed to promote increases in physical activity level and reductions in energy intake among overweight and obese men and women aged 35 to 74 years. The secondary objectives were to examine whether any changes in activity or diet achieved by the intervention were sufficient to generate clinically meaningful changes in metabolic control and/or anthropometric risk markers for developing T2DM and CVD.

It was predicted that the intervention would bring about changes in PA and diet via the following hypothesised mechanisms:

1. The intervention would lead to increases in autonomous motivation and self-efficacy for PA and consuming a healthy diet.
2. The intervention would increase self-regulating behaviours (action planning, coping planning, self-monitoring) for PA and healthy eating.
3. Increases in autonomous motivation and self-efficacy would predict increases in self-regulatory behaviours.
4. Intervention effects on PA and energy intake would be mediated by self-regulatory behaviours.
5. Habit strength and social support would, in addition to self-regulatory behaviours, mediate the intervention effects on PA and energy intake.

The complete hypothesised process model is displayed in Figure 5.1. Autonomous motivation and self-efficacy have shown strong, positive associations with self-regulatory behaviours, and weight control and physical activity (Nurmi et al., 2016; Teixeira et al., 2015). For reasons of parsimony (in terms of a process analysis) and in order to reduce participant burden, it was decided to focus on autonomous motivation and self-efficacy as mediating cognitive determinants. The additional cognitions assessed in Study 2 (beliefs, outcome expectations, attitudes and perceived controllability) were not included here; although some of these cognitions were found to significantly increase with exposure to Study 2 resources, there is little evidence linking them to self-regulatory behaviours. Intention was also not included in the present study in order to reduce participant burden; it had been used in Study 2 as a proxy for behaviour but in the current study actual behaviour was measured instead.

Figure 5.1 Hypothesised process model of intervention effects on PA and dietary behaviours

In addition, participants' perceptions of and experience with the intervention were investigated to gain insight into its acceptability and feasibility of further implementation.

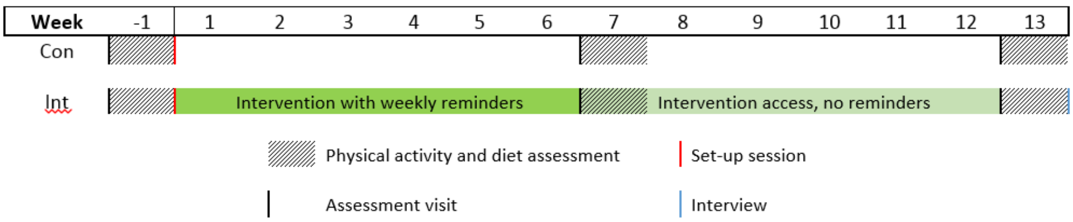
5.2 Methods

The methods used are reported here in accordance with the CONSORT guidelines for trials of non-pharmacologic treatment (Boutron et al., 2008).

5.2.1 Design

An exploratory randomised controlled trial (RCT) was conducted with two parallel groups (registered on www.clinicaltrials.gov, ref: NCT03032731). A cross-over design was not possible as once the intervention had been received its informational content could not be intentionally forgotten. After initial screening, participants were allocated to receive either information about freely available NHS website resources (control group) or the Evolife intervention (intervention group), using a minimisation calculation to balance the groups for age, gender and BMI (Treasure & MacRae, 1998). PA, dietary, health and psychosocial variables were assessed at baseline, six- and twelve-weeks after starting the intervention (or receiving the control information). For the first six weeks, participants in the intervention group received weekly reminders to record their progress towards behavioural goals and set new goals and plans for the coming week. After six weeks, the weekly reminders stopped but participants were still able to use the monitoring and goal setting features of the intervention. After the 12-week assessment, participants in the intervention group were invited to take part in a one-to-one, semi-structured interview to share their experience and opinions of the intervention. Figure 5.2 gives an overview of the study design.

Figure 5.2 Overview of study design



The study received ethical approval from the Research Ethics Approval Committee for Health (REACH) at the University of Bath on 28th October 2016 (ref. EP 16/17 034).

5.2.2 Sample size and allocation

A sample size of 54, with 27 participants in each group, was calculated as the minimum required to detect a meaningful change in physical activity level (PAL; defined as total daily energy expenditure divided by basal metabolic rate); this calculation used a predicted effect size of 0.68, which was the effect size found in a similar intervention study conducted with a similar population of inactive, overweight adults (Western, 2017), with power of 0.80 and alpha of 0.05. To allow for drop-outs, a recruitment target of 58-60 participants was set.

Following the baseline assessment visit, participants were allocated to one of the two groups using a concealed minimisation procedure, which dynamically adjusts allocation probabilities in order to minimise differences between groups on important covariates (Taves, 1974; Treasure & MacRae, 1998). As a participant joined the study, a researcher in the University (who otherwise was not involved with the study in order to limit bias (Treasure & MacRae, 1998)) entered the participants' age, gender and BMI values into an Excel database programmed to calculate group allocations such that differences in age, gender and BMI between groups would be minimised (adapted from Hopkins, 2010). Blinding to intervention allocation was not possible for anyone involved in the trial since participants would know whether or not they received an intervention and there was only one researcher to conduct both the introductions to the intervention and control groups and the assessments.

5.2.3 Participants and recruitment

Men and women aged between 35 and 74 years (inclusive) and with a body mass index (BMI) of at least 25kg/m^2 but less than 40kg/m^2 were eligible to take part. The study was advertised on the University of Bath website, in the local press, on Twitter and via advertisements sent to local businesses. All advertisements stated brief details of what participation would involve, the eligibility criteria, that participation would be confidential and contact details of the researcher. Those who responded to recruitment advertisements were first screened, via email or telephone, for eligibility and only sent a participant information sheet if they met inclusion criteria. Participants had to be fluent in English and have access to the Internet. As the focus of the intervention was on prevention, individuals were excluded if they had been diagnosed with coronary heart disease, chronic kidney disease, type 1 or type 2 diabetes, stroke, heart failure, severe hypertension (BP>180/110mmHg), peripheral arterial disease or thyroid disorders. An upper BMI limit was set at 40kg/m^2 as current guidelines suggest that lifestyle change alone may not be the most appropriate intervention in these cases, rather bariatric surgery followed by lifestyle intervention is recommended (National Institute for Health and Care Excellence, 2014b). In order to assess the effects of the intervention in isolation, individuals were also excluded if they were currently taking any medications that could affect their body mass, were going through the menopause, were taking part (or had participated within the last 2 months) in another lifestyle intervention, or had recently undergone a large change in habitual lifestyle or body mass.

Those who met the eligibility criteria and remained interested in participating after reading the information sheet were given the opportunity to ask the researcher any questions about the study before being sent a consent form to complete. When consent had been received, a baseline assessment appointment was scheduled.

5.2.4 Assessments

Three assessment visits at a laboratory in the University of Bath's Department for Health took place for each participant: at baseline, six weeks and 12 weeks after starting the intervention/control condition. Participants were asked to arrive for assessment visits in the morning, in a fasted state (having consumed nothing except water since 10PM the day before). On arriving at the lab, participants were asked to complete a questionnaire pack (see section 5.2.7.2). This took between 15 and 25 minutes and was done while participants were sitting down, thus helping their blood pressure to stabilise after walking to the lab. Blood pressure was then recorded while the participant was still seated. Next, height, body mass and waist circumference were measured before taking a 10ml blood sample.

Finally, the researcher gave participants a BodyMedia accelerometer to wear for the seven days following the assessment visit, along with a 3-day food diary and set of kitchen scales to also complete over the following week. Full instructions on both the activity monitor and food diary were explained by the researcher and given in printed form for the participants to take away. The researcher emphasised the importance of maintaining normal activity and diet during the monitoring period and recording everything consumed whether or not it was thought to be 'good' or 'bad'. Activity monitors and diaries were collected by the researcher approximately eight days after the assessment visit (i.e. when a full seven days of activity had been recorded). For participants in the intervention group, interviews took place when the monitors and diaries were collected after the 12-week assessment.

5.2.5 Control condition

The control condition aimed to mimic usual advice given to NHS patients who have been advised to lose weight and increase PA to prevent diabetes or cardiovascular disorders (e.g. after receiving a moderate or high risk score in an NHS Health Check (Public Health England, 2014)) or who request advice on healthy living and losing weight. For participants allocated to the control group, a set-up meeting was arranged at the end of the baseline 7-day monitoring period, either at the university or in a convenient public place. During this meeting, the accelerometer and diet diary were collected and the researcher provided brief information about losing weight, healthy eating and PA, and their importance for preventing T2DM and CVD. This information was taken from publicly available NHS websites (NHS Choices, Change4Life and One You), which the researcher also showed to the participants, highlighting specific areas of the websites that the person might find helpful for making behaviour changes (e.g. where to download exercise and meal planning apps, where to find information on locally available services). The same information and websites were discussed with all participants in the control group. Participants were given an information sheet to take away, which listed the three websites and summarised what was available on them. These meetings lasted approximately 20 minutes and the researcher followed a schedule to ensure that the same information was discussed with each participant. At subsequent assessment points, participants were asked if they had used any of the NHS resources or had sought/received any support from other sources. Other than arranging 6- and 12-week assessments, no contact was made between the researcher and participants in the control group between meetings.

At the end of the study, participants in the control group were offered the chance to try the Evolife intervention. The opportunity to try the intervention had been included in recruitment materials in an attempt to ensure retention of participants.

5.2.6 Evolife intervention

5.2.6.1 Overview

The Evolife intervention was based around a website (see section 5.2.6.2) developed specifically for this study. The website aimed to provide participants with information, framed from an evolutionary mismatch perspective, about PA and healthy eating, and advice on how to make behavioural changes to improve health. The website also provided a platform for participants to set activity- and diet-related goals and monitor their progress towards these. One of the goals participants were encouraged to make was a step goal and in order to help with this they were given a pedometer. In order to help set diet-related goals, participants were asked to complete a short food frequency questionnaire (FFQ) adapted from the British Heart Foundation's 'How healthy is your diet?' questionnaire; the researcher compiled brief feedback based on the responses and emailed this to participants shortly after the set-up session. The feedback highlighted both good aspects of the participant's diet and aspects that could be improved, along with suggestions of changes that they could try. The behaviour change techniques included in the intervention are displayed in Table 5.1 and Appendix 5.1 describes the intervention according to the Template for Intervention Description and Replication guidelines (TIDieR; Hoffmann, Glasziou, Boutron et al., 2014).

For participants allocated to the intervention group, a set-up meeting was arranged at the end of the baseline 7-day monitoring period, either at the university or in a convenient public place. During this meeting, the accelerometer and diet diary were collected and then participants were asked to complete the FFQ. Following this, the researcher provided an introduction to the intervention, giving an overview of the evolutionary mismatch concept and how it relates to health today, then explaining that the Evolife website aimed to help participants learn more about their health from an evolutionary perspective, learn how to make changes to their behaviour in a sustainable way and help them to make behavioural goals and monitor their progress. After talking through this introduction, the researcher showed the participant the various areas and features of the website (using either a PC or tablet computer), particularly focusing on the goal setting and recording area while encouraging participants to explore the more informational pages in their own time. The researcher discussed with participants what types of goals, besides the step goal, they might like to set, providing examples, asking about daily routines and encouraging participants to set goals that would provide an element of challenge while also considering potential barriers. Participants were advised to read the information on the website about goal setting, planning and social support before setting their goals. Participants were also shown how to use the pedometer and access previous days' step counts in the memory – after the researcher had demonstrated this, participants were able to practise using the pedometer while the researcher was present to answer any questions. To help standardise the set-up sessions, the researcher followed a schedule that set out the order in which topics should be discussed and provided prompts to ensure the same elements were covered. There was, however, a certain degree of variation to allow participants' questions to be answered, particularly regarding goal setting. In responding to questions, the researcher gave the same information as could be found on the website.

Access to the website was password protected, enabling each participant to have a unique and private profile, storing all their data and personalising the home and goal setting pages to display an individual's information. Following the set-up session, participants were sent a unique link to the website (via email) that asked them to set their own password.

For the first six weeks of the intervention, participants in the intervention group were sent weekly reminders by email to record their steps and progress for the other goals, and to adjust their goals/plans, if necessary, for the coming week. After three weeks, these emails also encouraged participants to look again at the information pages, to reinforce their knowledge and potentially boost motivation.

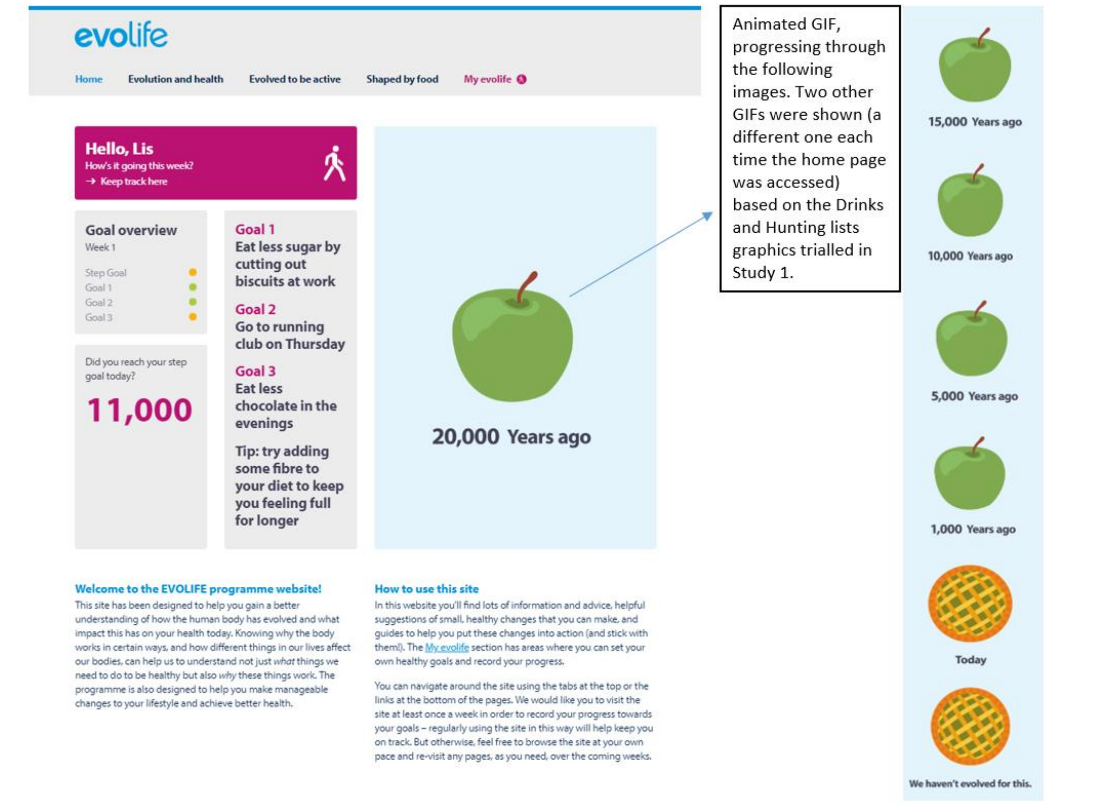
Table 5.1 Behaviour change techniques included in the Evolife intervention

BCTs (Taxonomy v.1, 2013)	Delivery
Goal setting (behaviour)	Face-to-face in introductory session with researcher and online
Action planning	Face-to-face in introductory session with researcher and online
Problem solving (coping planning)	Face-to-face in introductory session with researcher and online
Prompt mental rehearsal of successful performance	Face-to-face in introductory session with researcher and online
Feedback on behaviour	Face-to-face in introductory session with researcher, email and pedometer feedback and online
Prompt habit formation	Face-to-face in introductory session with researcher and online
Information about health consequences	Online
Information about antecedents	Online
Demonstration of the behaviour	Online
Social support (practical and emotional)	Online
Prompt restructuring the social environment	Online
Self-monitoring of behaviour	Pedometer and online

5.2.6.2 The Evolife website

Content for the website was developed from the resources used in Study 2, with amendments and additions made to address feedback obtained both in Study 2 and pilot testing of the website pages (e.g. information on different food groups, inclusion of information on alcohol, more examples of behaviours to try and food swaps to make). Graphic designers and web developers were employed to help create a professional-looking, attractive and user-friendly site. In particular, interactive graphics were developed that aimed to increase active engagement with the website and help illustrate some of the informational text. Content aiming to incorporate established behaviour change techniques (e.g. engaging social support and goal setting) was also added, informed by previous research and composed, where possible, to link with the evolutionary mismatch concept. The website could be accessed both on PCs and mobile devices.

Figure 5.3 Website home page, showing the section tabs at the top of the screen



The Evolife website contained a home page and four sections: Evolution and health; Evolved to be active; Shaped by food; and My Evolife. The home page displayed a personalised greeting, the user's goals, a traffic light display indicating progress towards the goals that week (i.e. green = goal reached, amber = goal almost reached etc.), an animation of an evolutionary mismatch message (three animations were used, a different one displayed each time the page was refreshed), and a brief section of text on how to use the website (see Figure 5.3). The 'Evolution and health' section contained three pages, giving an overview of human biological and cultural evolution, and what implications this has for health. The 'Evolved to be active' section consisted of six pages, the first four of which giving factual information about the decline of PA in recent years and why PA is important for health, with particular focus on the importance of muscle for sugar metabolism. A 'Tips from our ancestors' page aimed to highlight how much more activity humans did even 50 years ago while also providing suggestions for achievable ways to incorporate more PA into everyday life. The final page in this section gave an 'Interview with John', a narrative trialled in Studies 1 and 2 and written from the perspective of a middle-aged man who tried increasing his PA after receiving a 'high risk' diagnosis at his NHS Health Check. The 'Shaped by food' section followed a similar format to 'Evolved to be active', with four factual information pages explaining the changes in human diet over the years and looking at how this affects the body, with particular emphasis on fat tissue, a 'Tips from our ancestors' page and a narrative page, this time written from the perspective of Cathy, a woman who made dietary changes. Both Tips pages contained links to relevant sections of external websites (NHS Choices and One You, and the British Nutrition Foundation), where participants could find more information about activities to try and food swaps to make. The website can be visited at www.evolifebath.co.uk (Username: Guest; Password: evolifeguest). The text content is available in Appendix 5.2 and screen shots from a selection of the website pages can be found in Appendix 5.3.

The final section of the website, My Evolife, focused on providing specific techniques to support healthy behaviour changes: the first page gave a brief reminder of the mismatch concept to enforce the evolutionary rationale for behaviour change; the next three pages gave information on and examples of setting goals (using the SMART method, i.e. setting goals that are Specific, Measurable, Achievable, Relevant, and Time-bound), monitoring progress and planning to overcome barriers (using the If-Then action planning method), and managing social situations (including engaging social support in order to attain goals). The final page, 'Keeping Track', provided a space for participants to set goals and record and monitor their progress. At the top of the page, a goal chart displayed an overview of the participant's progress on meeting their goals over the previous weeks. For each goal a coloured dot appeared beneath the relevant week number, with a red dot depicting a goal that had not been met, an amber dot depicting a partly met goal and a green dot depicting a fully met goal (see Figure 5.4). Below this chart were sections to set a daily step goal and up to three other goals. After setting a daily step goal, participants could enter their seven total step counts for each day that week; when these were saved, a line graph was populated showing each day's steps, with a reference line displaying the target (see Figure 5.5). For the three other goals, two free-text boxes were provided for participants to enter a goal and a plan of how they would reach their goal. It was not possible to create unique formats of recording progress for individual goals for each participant, instead a standard multiple choice question was displayed for participants to record at the end of the week whether they had achieved, partly achieved or not achieved their goal (see Figure 5.6). Feedback messages were displayed in a pop-up window when participants saved all their step counts for the week or progress on the other goals: for each type of goal there were three possible messages depending on whether participants had fully, partly (e.g. reached the daily step goal on five days of the week) or not met their goal. The messages were short and aimed to praise the individual's achievement and/or encourage them to keep trying, and prompt them to try increasing their goal for next week or changing their plan to help them overcome any barriers they came across.

Figure 5.4 Goal overview chart

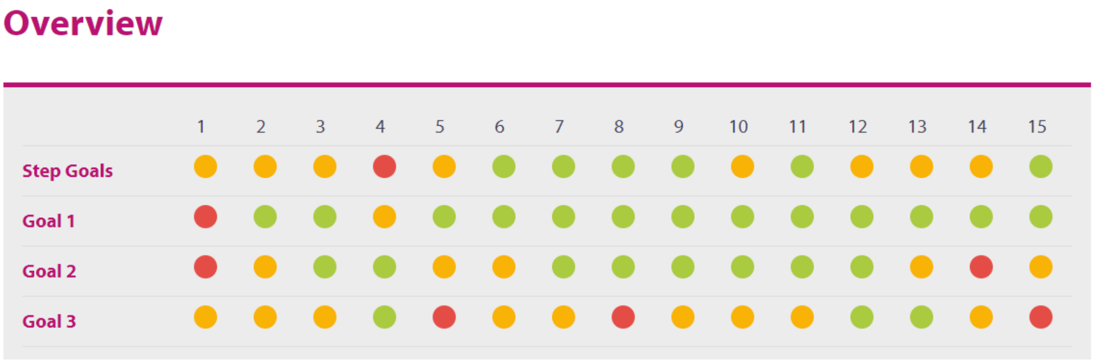


Figure 5.5 Step goal section

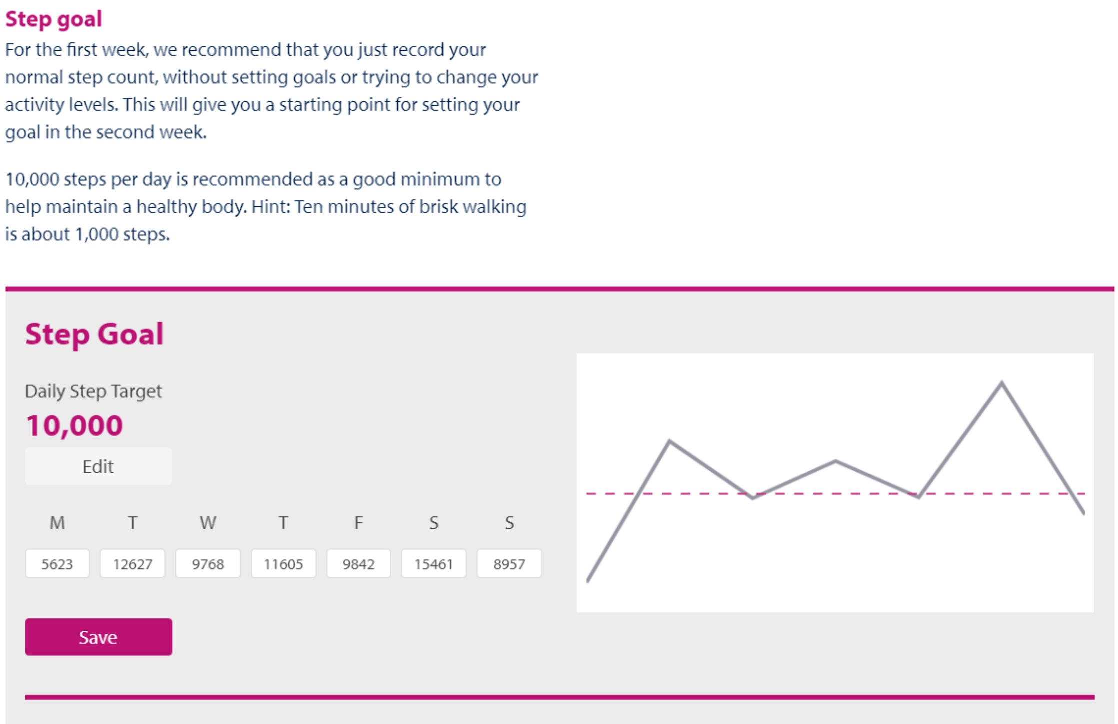
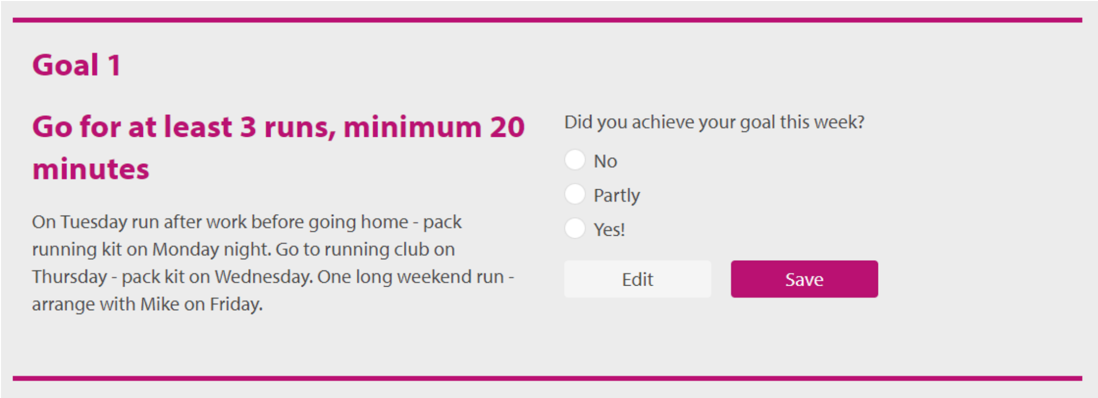


Figure 5.6 Open goal recording area



5.2.6.3 Pedometers

Intervention group participants were given a Yamax EX210 3D digital pedometer (see Figure 5.7). This model was chosen for its small size, ease of use and 7-day memory, meaning participants would not have to log their steps on the website every day (which might have been burdensome) but would need to visit the website at least once a week in order to record their step counts before they were deleted from the pedometer. The devices can be worn on a clip on a waistband, on a strap attached to a belt loop or in a pocket – in order to improve accuracy participants were advised to wear the pedometer close to their body and avoid letting it swing on the strap. Yamax pedometers are frequently used in research, both as intervention materials (e.g. Harris et al., 2017) and as assessment tools (e.g.Presset, Laurenczy, Malatesta & Barral, 2018).

Figure 5.7 Yamax EX210 3D pedometer

5.2.7 Outcomes

5.2.7.1 Primary outcome measures

The primary outcomes were mean daily physical activity level (PAL) and mean daily energy intake (EI: measured in kilocalories, kcal). PA was measured using BodyMedia SenseWear monitors (BodyMedia Inc., USA). These are wireless multi-sensor monitors worn on the upper arm (over the triceps muscle) that integrate motion data from a three axis accelerometer with other physiological responses (heat flux, skin temperature and galvanic skin response). The device is lightweight (about 80g) and held in place with a device-specific elasticated armband (see Figure 5.8); it is unobtrusive, comfortable to wear and can be fitted by the participant with minimal instruction. The BodyMedia armband has been shown to provide valid and reliable measures of PA energy expenditure (Berntsen et al., 2010; Johannsen et al., 2010; Welk, McClain, Eisenmann & Wickel, 2007). Data from the monitors was processed using SenseWear Professional Version 8 software, which calculates the energy expenditure of each minute of data using complex pattern recognition algorithms. A Naïve Bayes classifier is used to match the armband data to the activity class that best describes the current minute (e.g. sedentary, moderate activity etc.). Each activity class has a linear regression model, mapping the sensor values and body parameters to energy expenditure.

Figure 5.8 BodyMedia armband

Participants were asked to wear the monitor for seven complete days (each day taken from midnight to midnight), only removing it for water-based activities (e.g. showering, swimming). To be included in the analysis, a minimum of five valid days (including a Saturday and Sunday) of data was required; this is the minimum amount needed to gain a reliable measure of habitual PA (Scheers, Philippaerts & Lefevre, 2012). A valid day was one in which there was data for at least 80% of a 16-hour waking period[3]. Gaps in the data (e.g. when the monitor was removed for showering) were replaced with estimated basal metabolic rate (BMR), calculated using the age and gender specific Schofield equation (Schofield, 1985). Participants were asked to record any times the monitor was removed for anything other than showering/bathing or sleeping – the only other activity reported, by two participants, was swimming and in these cases the relevant data gaps were replaced with standard energy expenditure values for

[3] A few participants removed the monitors at night as, particularly during hot weather, they found them uncomfortable to wear while sleeping.

recreational swimming taken from the Compendium of Physical Activities (Ainsworth et al., 2011).

The total energy expenditure (TEE) data collected by the monitors was used to calculate PAL (PAL = TEE/BMR), which was the primary PA-related outcome. The data recorded by the monitors also enabled calculation of the time participants spent in various energy expenditure thresholds: sedentary = MET < 1.8, light intensity = 1.8 ≤ MET < 3, moderate intensity = 3 ≤ MET < 6, vigorous intensity = 6 ≤ MET < 10.2 and total moderate and vigorous activity, MVPA ≥ 3 MET (where MET = metabolic equivalent). The activity monitors also recorded step counts.

Energy intake was measured using 3-day weighed food diaries, incorporating two weekdays and one weekend day, completed during the weeks that participants were wearing activity monitors. Participants were given a set of digital scales (Model 'Disc 1036', Salter, Kent, UK) and a diary in which to record everything they ate and drank on monitoring days. Nutritics online software (version: 4.315 Education, United Kingdom) was used to perform detailed nutrition analysis of participants' food diaries. Three-day diaries, to include one weekend day, have been shown to be sufficiently representative of weekly habitual food intake (Fyfe et al., 2010) and were chosen for this study (over 7-day diaries) to minimise participant burden. Mean daily energy intake (in kilocalories, kcal) was the primary dietary outcome. The food diaries also enabled assessment of diet quality in terms of nutrient intake; in particular fibre, sugar and saturated fat intake was assessed.

It was obviously not possible to mask from participants the fact that their activity and diets were being monitored at the three time points, which could have led to a Hawthorne effect, i.e. participants may have changed their behaviour, consciously or unconsciously, as a result of knowing they were being observed. The importance of continuing their normal behaviour (i.e. how they behaved in the weeks immediately prior to the monitoring periods) was emphasised to participants both in terms of validity of the study and accuracy of the individual feedback that participants would receive.

5.2.7.2 Secondary outcome measures

Anthropometric and blood markers of health status were taken to assess whether any behavioural effects of the intervention had brought about physiological changes in the risk status for type 2 diabetes and cardiovascular disorders.

Anthropometrics

Blood pressure was measured using a digital sphygmomanometer (Model: EW3106, Panasonic, UK & Ireland). Three readings were taken and an average of these calculated. Waist circumference was measured with a non-stretch measuring tape (Model: 201, Seca, UK), placed approximately mid-way between the lowest rib and the iliac crest, while participants were standing and had completed a gentle exhalation (World Health Organization, 2008). Three waist circumference readings were taken and the mean value calculated. Height was measured to the nearest millimetre using a wall-mounted stadiometer (Seca, UK), participants first removed their shoes. Participants remained barefoot and were also asked to remove jackets and all items from their pockets before being weighed on digital scales (Model: BC-543, Tanita, Amsterdam, The Netherlands), which provided readings to the nearest 100g.

Blood biomarkers

Blood samples were taken by venepuncture: a 21G needle (BD Valu-Set, Becton Dickenson & Co., Plymouth, UK) was inserted into an antecubital forearm vein and a syringe (BD Valu-Set, Becton Dickenson & Co., Madrid, Spain) used to draw a 10ml sample. Blood was dispensed into collection tubes (Sarstedt Ltd., Leicester, UK): 5ml in serum tubes containing separator beads and 5ml in plasma tubes containing potassium ethylene-diamine-tetra acetic acid (EDTA – an anticoagulant). Samples were dispensed first into serum tubes to avoid contamination of the syringe with EDTA, which may have affected some metabolite measurements in the serum sample. Following gentle inversion, plasma tubes were immediately spun at 5000rpm (3645g) for 10 minutes at $4^{\circ c}$ in a centrifuge (Heraeus Biofuge Primo R, Bishops Stortford, UK). Blood in the serum tubes was mixed by gentle inversion and left to clot at room temperature for approximately 20 minutes before being spun. Samples were then transferred to 1.5ml Eppendorf tubes (Eppendorf, Stevenage, UK) and frozen at $-80^{\circ c}$ for analysis at the end of the study. Analysis was completed in batches with each participant's samples from all three time points being analysed in the same batch. Total cholesterol, HDL cholesterol, triglycerides, glucose and high-sensitivity C-reactive protein (CRP – a marker of inflammation) concentrations were measured from plasma using assay kits (Randox Laboratories, Crumlin, NI) in a Daytona automated analyser (Rx Series, Randox Laboratories, Crumlin, NI). LDL cholesterol was calculated using the Friedewald equation (all measurements in mmol/l; Friedewald, Levy & Fredrickson, 1972):

$$\text{LDL cholesterol} = \text{Total cholesterol} - \text{HDL cholesterol} - (\text{triglycerides}/2.2)$$

Insulin was measured in serum by enzyme-linked immunosorbent assay (ELISA; Mercodia, Sweden). Samples from each time point for each participant were included on the same ELISA plate for analysis. Insulin resistance was calculated from the fasted glucose and insulin scores using the homeostasis model assessment for insulin resistance (HOMA-IR; Matthews, Hosker, Rudenski et al., 1985):

$$\text{HOMA-IR} = \frac{\text{Fasting glucose (mmol/l) x Fasting insulin (mU/l)}}{22.5}$$

Questionnaires

Questionnaire packs contained demographics questions (only included in the baseline questionnaire) and a series of validated questionnaires, several of which are described in the previous chapter (please see Appendix 5.4 for the complete baseline questionnaire pack). The EQ-5D-3L (van Reenen & Oppe, 2015) was used to measure perceived health status. It consists of a visual analogue scale (the EQ VAS) running from 0 to 100, on which participants indicate where their health lies on the continuum from 'the worst health you can imagine' (rated 0) to 'the best health you can imagine' (rated 100), and five multiple choice questions concerning the following 'dimensions' of health: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. For each of the five dimensions participants are asked to indicate their current health state, choosing one of three options (no problems, some problems or extreme problems). The EQ-5D-3L is widely used and has been translated and validated in 170 languages (Brooks, 1996; van Reenen & Oppe, 2015).

The BREQ-3 (Markland & Tobin, 2004; Wilson et al., 2006) was adapted to assess motivation for PA and healthy eating, as described for Study 2. Self-efficacy was measured using the BARSE, adapted for PA, and Pawlak and Colby's (2009) self-efficacy scale for eating a healthy diet (both as described for Study 2).

Process measures assessed the following self-regulatory behaviours: action planning, coping planning, self-monitoring and social support. Adapted versions of the 9-item instrument developed by Sniehotta, Schwarzer, et al. (2005) were used to assess action and coping planning. With this instrument, participants were asked to rate on a 4-point scale the degree to which they agreed or disagreed that they engaged in various forms of planning. For PA, four items assessed whether participants had made action plans concerning when, where, how and how often to be physically active. For diet, three items assessed whether participants had made action plans concerning what to eat, what unhealthy foods to restrict and what healthy foods to include. To reduce participant burden, as has been done elsewhere (Gillison et al., 2015), only three of the original five items were used for coping planning for both PA and diet ('identifying good opportunities for action' and 'acting in line with intentions' were removed as they were deemed further from the coping planning construct than the other items). A five-item instrument developed by Gillison and colleagues (2015) was used to assess self-monitoring of PA and healthy eating over the last month. On this instrument, participants were asked to rate on a 4-point scale the degree to which they agree or disagree with statements such as 'I have consistently monitored what I eat and how healthy it is'.

Social support for PA was assessed with a 5-item instrument, developed by Roesch and colleagues (2010), on which participants rated, on 5-point Likert scales (from 1 = almost never to 5 = very often), how often during the past month they received different types of support from family or friends. Social support for healthy eating was measured with a similarly formatted, 6-item instrument compiled by Norman and colleagues (2010). Both instruments have shown good reliability and validity in large samples of overweight adults.

To assess the extent to which PA and healthy eating were habitual to participants, the shortened Self-report Habit Index (Gardner et al., 2012) was also included in the questionnaire pack. This instrument contains four items to which participants rate their agreement on 7-point scales.

5.2.7.3 Interviews

All participants in the intervention group were invited to take part in a one-to-one semi-structured interview after they had completed the 12-week assessments. The interview schedule (Appendix 5.5) was designed to gain an understanding of participants' experience of the Evolife intervention and their opinions concerning what aspects of the intervention were helpful and how it could be improved. Interviews were recorded with an Olympus VN-732PC digital recorder and audio files uploaded to a computer for analysis. To help ensure the credibility (i.e. internal validity, Shenton (2004)) of findings, the researcher encouraged participants to be honest, inviting both praise and criticism of the intervention and building on the rapport that had been developed over the course of the study.

5.2.8 Analysis

The primary analyses compared, separately, the 12-week change in PA (mean PAL) and dietary intake (total energy) of the intervention and control groups using analysis of covariance (ANCOVA) models (Laird, 1983). Baseline values of PAL and total energy intake were entered as covariates to control for chance imbalances at baseline, as well as the factors used in group allocation, i.e. sex, age and baseline BMI (Hopkins, Marshall, Batterham & Hanin, 2009; Scott, McPherson, Ramsay & Campbell, 2002). ANCOVAs were also used for analysis of health outcome (anthropometrics and blood markers) and psychological data, controlling for baseline discrepancies in the dependent and allocation factors. Missing data was deleted listwise in all analyses.

To assess the pathways of how the intervention is hypothesised to affect PA and energy intake, a series of regressions and process analyses were conducted. Multiple regressions were used to test whether autonomous motivation and self-efficacy predicted self-regulatory behaviours at 12 weeks. The mediation pathways of hypotheses 4 and 5 (i.e. self-regulatory behaviours, habit strength and social support mediating the effects of the intervention on PA and healthy eating) were explored using the PROCESS v2.16.3 macro for SPSS (Hayes, 2013) to calculate bias-corrected 95% confidence intervals (CI) of total, direct and indirect effects, based on 5000 bootstrap iterations and including all participants. Baseline measures of all variables were included as covariates. Although the model includes both serial (e.g. autonomous motivation predicts action planning) and parallel (e.g. action planning, coping planning and self-monitoring are conceptualised to occur at the same level) mediation pathways, PROCESS v2.16.3 macro could not conduct such models. Thus Hypotheses 4 and 5 contained only parallel mediation pathways and the predicted serial pathways were tested separately in Hypotheses 1 and 3. Given the small sample size it was not possible to conduct a structural equation modelling analysis including autonomous motivation and self-efficacy as well as the self-regulatory behaviours.

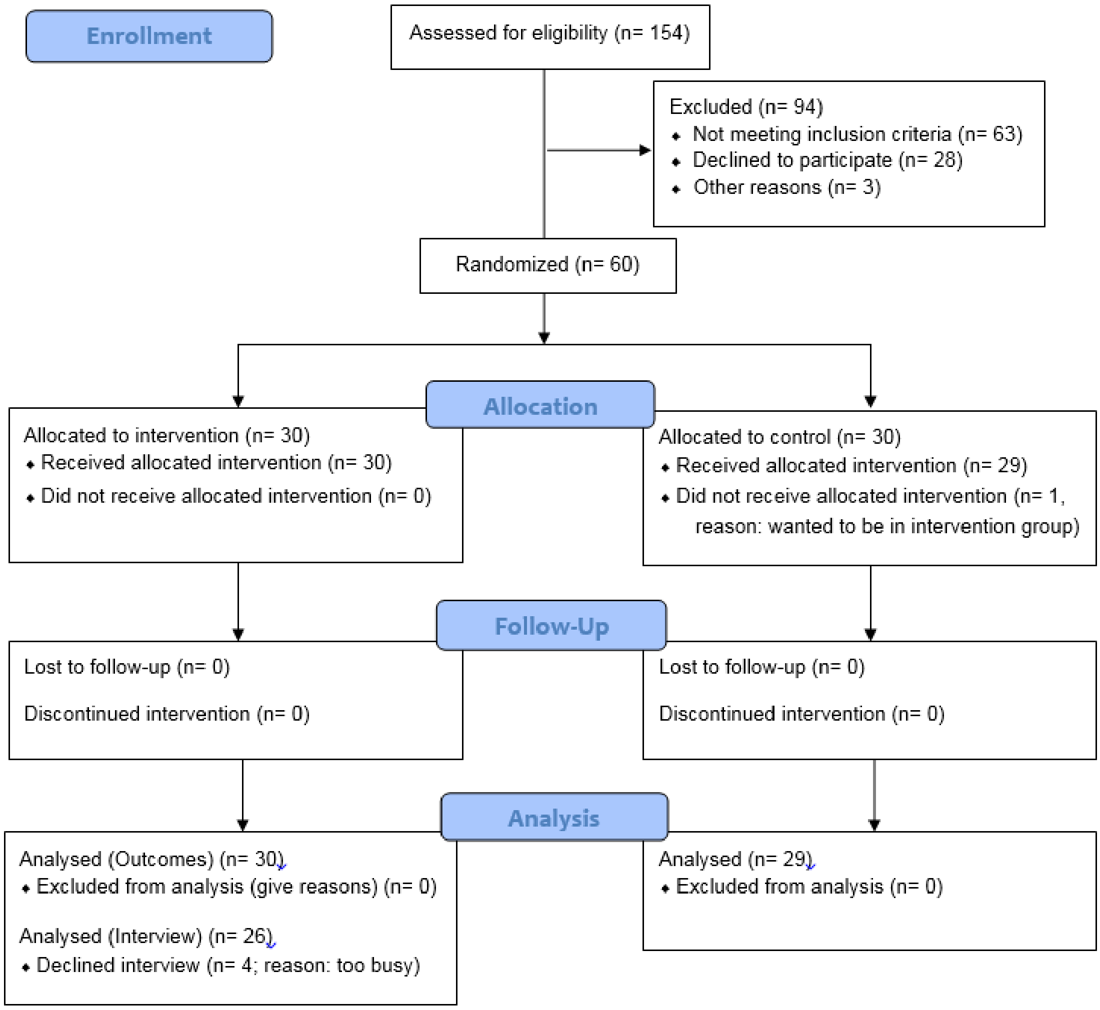
A thematic framework analysis was conducted with the interview data, using a framework approach, to explore acceptability and feasibility of the intervention (Hsieh & Shannon, 2005; Pope et al., 2000). The researcher first listened to all the recordings at least twice to become familiar with the data, noting down any interesting or recurring issues and themes that emerged. These issues/themes were then reviewed and used to help inform, along with previous literature and the research aims, a ‘framework’ of themes. Each recording was then listened to again, this time indexing the data within the framework – relevant quotations or summaries of the data being organised into separate themes in an Excel spreadsheet. To help ensure dependability and confirmability of the process (Meyrick, 2006; Shenton, 2004), the thematic framework was discussed among the research team.

5.3 Results

5.3.1 Recruitment and retention

The flow of participants is shown in Figure 5.9. Initial enquiries about participation were received from 154 people; 60 (38.9%) met the inclusion criteria and were allocated between the two groups from January to June 2017. After allocation, one participant dropped out of the control group before completing the baseline monitoring period – this participant was therefore excluded from analysis. All other participants attended all three assessment visits and are included in the analysis. Outcomes assessed in blood could not be obtained for one participant in the intervention group due to difficulty in blood sampling. Complete PA and dietary intake data were obtained from all 59 participants at baseline. Due to a monitor failure, no PA data were collected from one control group participant at 6 weeks. Insufficient PA data were collected at 12 weeks from two participants, one in each group. Thus, complete PA data were available for 58 participants at 6 weeks and 57 participants at 12 weeks. Total 24-hour wear time of the activity monitors during the three assessment periods was good: on average, monitors were worn for 97%, 94% and 94% of the time by intervention group participants and 97%, 96% and 97% by control group participants. One participant in the intervention group did not provide sufficient dietary intake data at 6 and 12 weeks. Dietary intake data were not received from three control group participants at 12 weeks, leaving total sample sizes for dietary intake data of 58 at 6 weeks and 55 at 12 weeks.

Figure 5.9 CONSORT diagram of participant flow through the study



5.3.2 Sample characteristics

Baseline characteristics and cognitions of the sample are displayed in Table 5.2. Using independent t-tests (continuous data) and Chi-squared tests (categorical data), no significant differences were found between groups for the variables displayed in Table 5.2. Fifty-six percent of the sample was male and 95% white with a mean age of 50 years and mean BMI of 30.3kg/m^2. The majority of the participants were married (66%), employed (90%) and educated to at least undergraduate level (66%). The mean index of multiple deprivation (IMD) of 7.61 indicates that the sample were reasonably affluent, living in areas considered to be in the 30-40% least deprived in England.

Table 5.2 Sample baseline characteristics

		Intervention (N = 30)	Control (N = 29)
Gender, N (%)	Male	17 (57)	16 (55)
	Female	13 (43)	13 (45)
Age, M (SD)		50.3 (8.9)	49.5 (9.1)
Age, min-max		35 - 70	35 - 68
BMI, M (SD)		30.3 (4.2)	30.3 (3.0)
Ethnicity, N (%)	White	27 (90)	29 (100)
	Black/Black British	1 (3)	-
	Asian/British Asian	1 (3)	-
	Other	1 (3)	-
Marital status, N (%)	Single	5 (17)	2 (7)
	Stable relationship	3 (10)	7 (24)
	Married/civil partnership	20 (67)	19 (66)
	Divorced/separated	2 (7)	1 (3)
Employment, N (%)	Full time employment	22 (73)	23 (79)
	Part time employment	4 (13)	4 (14)
	Student	1 (3)	-
	Retired	2 (7)	2 (7)
	Unemployed	1 (3)	-
Education, N (%)	No formal qualification	1 (3)	-
	GCSE or equivalent	1 (3)	3 (10)
	A level or equivalent	2 (7)	5 (17)
	HND or equivalent	3 (10)	5 (17)
	Bachelors	6 (20)	6 (21)
	Masters/postgraduate	11 (37)	6 (21)
	Doctorate	6 (20)	4 (14)
IMD (1-10), M (SD)		7.9 (2.1)	7.3 (2.7)
Smoking, N (%)	Never smoked	18 (60)	13 (45)
	Ex-smoker	12 (40)	13 (45)
	Currently smoke	-	3 (10)
Immediate relations with CVD, N (%)	Yes	7 (23)	7 (24)
	No	22 (73)	22 (76)
	Missing	1 (3)	-
Immediate relations with T2DM, N (%)	Yes	6 (20)	7 (24)
	No	24 (80)	22 (76)
Self-rating of health (0-100), M (SD)		63.7 (14.6)	66.7 (19.3)
Perceived mobility (1-3)		1.03 (0.18)	1.10 (0.31)
Perceived ability (1-3)		1.17 (0.46)	1.10 (0.31)
Perceived pain (1-3)		1.27 (0.45)	1.31 (0.47)
Perceived anxiety/depression (1-3)		1.33 (0.48)	1.28 (0.46)

BMI = body mass index.. IMD = Index of Multiple Deprivation: 1 = most deprived 10%, 10 = least deprived 10%. Data for 28 participants in each group. T2DM = type 2 diabetes mellitus. CVD = cardiovascular disease There were no significant differences between groups for these characteristics at baseline.

5.3.3 Primary outcomes – physical activity and energy intake at 12 weeks

Physical Activity

Table 5.3 displays the baseline, 6-week change and 12-week change scores for PA parameters in the intervention and control groups. Table 5.4 shows the ANCOVA results, adjusted mean differences between the intervention and control groups and effect sizes for the PA parameters at 6 and 12 weeks. There was a non-significant difference of small effect size between groups' 12-week change scores for PAL, with the intervention group increasing their PAL to a slightly greater extent than the control group (adjusted mean difference (AMΔ) = 0.03, 95% CI = -0.05 to 0.11, d = 0.32). No significant differences between the control and intervention group were found for any of the other PA parameters at 12 weeks when adjusting for their baseline scores. However, adjusted mean difference scores indicated greater improvements for the intervention group of small but meaningful effect size for sedentary time (-9 min/day, 95% CI = -39 to 21, d = -0.25), vigorous activity (6 min/day, 95% CI = -3 to 15, d = 0.42), MVPA (7 min/day, 95% CI = -17, 31, d = 0.24), TEE (79 kcal/day, 95% CI = -56, 216, d = 0.36) and daily step count (560/day, 95% CI = -1145, 2265, d = 0.23). As can be seen in Table 5.3, improvements in PA made by the intervention group at the 6 week stage tended to be maintained or further improved by 12 weeks. The control group tended to have improved at 6 weeks (to a lesser extent than those in the intervention group) but these changes were not maintained at the 12-week stage.

Table 5.3 Mean (SD) baseline, 6-week change and 12-week change scores, and within group effect sizes (d) for physical activity in the intervention and control groups

	Intervention					Control				
	Baseline	6 wk change	d 6 wk change	12 wk change	d 12wk change	Baseline	6 wk change	d 6wk change	12 wk change	d 12wk change
Daily PAL (TEE/BMR)	1.64 (0.16)	0.04 (0.14)	0.23	0.06 (0.15)	0.33	1.71 (0.27)	<0.01 (0.20)	0.04	0.01 (0.16)	0.04
Sedentary* (min/day)	736 (73)	-17 (61)	-0.24	-24 (58)	-0.27	710 (109)	-12 (89)	-0.15	-10 (59)	-0.09
Light (min/day)	106 (43)	10 (34)	0.23	12 (33)	0.24	115 (47)	8 (42)	0.20	9 (29)	0.16
Moderate (min/day)	112 (50)	2 (37)	0.05	5 (35)	0.08	121 (76)	4 (55)	0.09	<1 (44)	0.02
Vigorous (min/day)	6 (7)	5 (12)	0.46	6 (18)	0.39	14 (17)	>-1 (10)	-0.03	>-1 (14)	-0.03
MVPA (min/day)	118 (54)	7 (40)	0.14	12 (44)	0.18	135 (87)	4 (60)	0.07	<1 (50)	0.02
TEE (kcal/day)	2906 (515)	37 (190)	0.07	67 (246)	0.14	2963 (636)	9 (274)	0.07	-23 (264)	0.01
Daily steps	7466 (3254)	1329 (3256)	0.33	793 (3756)	0.20	8237 (3844)	401 (1785)	0.14	63 (2307)	0.04

*To standardise sleep time, the sedentary score assumes 8 hours (480 minutes) of sleep per 24 hours for each person at each time point.
6wk = 6 weeks; 12wk = 12 weeks. At 6 weeks, intervention N=30, control N=28. At 12 weeks, intervention N=29, control N=28.
PAL = physical activity level; TEE = total energy expenditure; BMR = basal metabolic rate; MVPA = moderate to vigorous PA; min/day = minutes per day.
Positive effect sizes indicate an increase in the variable over time, negative effect sizes indicate a decrease over time. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Table 5.4 ANCOVA results (F), adjusted mean differences (AMΔ) between the intervention and control groups and between group effect sizes (d) for physical activity at 6 and 12 weeks

	6 weeks			12 weeks		
	F (df = 1, 52)	AMΔ* (95% CI)	d (95% CI)	F (df = 1, 51)	AMΔ* (95% CI)	d (95% CI)
Daily PAL (TEE/BMR)	0.001	-0.001 (-0.08, 0.08)	0.22 (-0.30, 0.74)	0.71	0.03 (-0.05, 0.11)	0.32 (-0.20, 0.84)
Sedentary (min/day)	0.23	8 (-26, 42)	-0.07 (-0.59, 0.44)	0.35	-9 (-39, 21)	-0.25 (-0.77, 0.27)
Light (min/day)	0.17	-4 (-21, 14)	0.05 (-0.47, 0.56)	0.06	2 (-15, 19)	0.11 (-0.41, 0.63)
Moderate (min/day)	0.38	-6 (-27, 14)	-0.04 (-0.56, 0.47)	0.07	3 (-17, 23)	0.13 (-0.39, 0.65)
Vigorous (min/day)	1.54	4 (-2, 10)	0.54 (0.01, 1.06)	1.65	6 (-3, 15)	0.42 (-0.11, 0.94)
MVPA (min/day)	0.14	-4 (-26, 18)	0.07 (-0.44, 0.59)	0.33	7 (-17, 31)	0.24 (-0.28, 0.76)
TEE (kcal/day)	0.01	5 (-109, 119)	0.12 (-0.40, 0.63)	1.38	80 (-57, 216)	0.36 (-0.17, 0.87)
Daily steps	1.34	830 (-610, 2271)	0.35 (-0.17, 0.86)	0.43	560 (-1145, 2265)	0.23 (-0.29, 0.75)

At 6 weeks, intervention N=30, control N=28. At 12 weeks, intervention N=29, control N=28.
PAL = physical activity level; TEE = total energy expenditure; BMR = basal metabolic rate; MVPA = moderate to vigorous PA; min/day = minutes per day.
*Covariates in the model included sex, age, baseline BMI and baseline values of the dependent variable. Negative adjusted mean difference scores indicate a greater change was found in the control group than the intervention group, except for sedentary time where negative values indicate a greater reduction was found for the intervention group.
Positive effect sizes indicate greater improvement (i.e. increased activity) in the intervention group, except for sedentary time where negative effect size indicates greater improvement (i.e. decreased time spent sedentary) in the intervention group. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Dietary outcomes

Baseline, 6-week change and 12-week change scores for dietary intake in the intervention and control groups are displayed in Table 5.5. ANCOVA results, adjusted mean differences between the intervention and control groups and effect sizes for dietary intake at 6 and 12 weeks are shown in Table 5.6. There was a non-significant difference of small to medium effect size between groups' 12-week change scores for total energy intake, with the intervention group reducing their intake to a greater extent than the control group (AMΔ = -214kcal/day, 95% CI = -481 to 53, d = -0.49). In terms of dietary quality, significant improvements as a result of the intervention were found for total fat intake at 12 weeks. Both groups reduced their fat intake, but there was a significantly greater reduction in total fat intake at 12 weeks in the intervention than the control group of small effect size (AMΔ = -12.15g/day, 95% CI = -24.68, 0.37; $F(1,49) = 3.8$, $p = 0.057$; d = -0.38). While there was a difference in the reduction of saturated fat intake of small effect size between groups at 12 weeks, the difference did not reach significance (AMΔ = -4.49 g/day, 95% CI = -9.75, 0.77; $F(1,49) = 2.94$, $p > 0.05$; d = -0.36). No other significant differences between the two groups were found on the dietary parameters. As can be seen in Tables 5.5 and 5.6, however, both groups had improved (i.e. reduced) their total carbohydrate, sugar and sodium intakes at 12 weeks and these reductions were meaningfully greater in the intervention group. Both groups had also made reductions, of small effect size, in their fibre and protein intake at 12 weeks and, for protein, a greater reduction was made by the intervention group. These were unintended as the Evolife intervention specifically suggested replacing fatty and sugary foods with high protein and fibre alternatives. However, relative to the reductions made in the other dietary parameters, the reductions in protein and fibre were of smaller effect size (for the intervention group only) and likely reflect the overall reduction in energy intake.

Over the course of the intervention, the changes in dietary intake made by participants tended to be maintained or increased from the 6-week to the 12-week stages. Similar trajectories were found for the control group in terms of total energy, carbohydrate, sugar and fibre intake. For total fat, saturated fat and protein, the control group had increased intake at 6 weeks but by 12 weeks had made reductions relative to baseline. The control group's sodium intake had reduced at 6 weeks but this reduction had lessened by 12 weeks.

Table 5.5 Mean (SD) baseline, 6-week change and 12-week change scores, and within-group effect sizes (d) for dietary intake in the intervention and control groups

	Intervention					Control				
	Baseline	6wk change	d 6wk change	12wk change	d 12wk change	Baseline	6wk change	d 6wk change	12wk change	d 12wk change
Total EI (kcal/day)	2246 (582)	-330 (678)	-0.60	-431 (694)	-0.81	2072 (547)	-28 (533)	-0.07	-124 (535)	-0.16
Total CHO (g/day)	244.6 (68.5)	-37.66 (82.01)	-0.58	-53.58 (85.13)	-0.83	219.3 (75.6)	-3.34 (55.88)	-0.06	-18.73 (65.65)	-0.21
Sugar (g/day)	101.0 (32.6)	-10.39 (29.80)	-0.36	-18.56 (29.35)	-0.57	89.5 (44.2)	-0.29 (30.11)	-0.04	-10.27 (39.94)	-0.23
Fibre (g/day)	24.0 (7.8)	-0.59 (10.38)	-0.09	-2.38 (8.67)	-0.36	23.2 (9.2)	-1.30 (7.76)	-0.16	-2.15 (7.11)	-0.27
Total fat (g/day)	85.4 (32.3)	-16.02 (33.44)	-0.58	-16.84 (34.90)	-0.60	83.3 (28.9)	1.51 (30.92)	0.03	-4.36 (31.45)	-0.09
Saturated fat (g/day)	33.4 (14.2)	-9.44 (13.74)	-0.80	-8.62 (15.63)	-0.68	31.8 (13.8)	0.45 (13.92)	0.02	-3.55 (11.96)	-0.22
Protein (g/day)	91.2 (28.0)	-7.70 (32.31)	-0.25	-11.80 (30.60)	-0.41	83.3 (20.4)	5.22 (25.57)	0.15	-3.73 (23.15)	-0.19
Sodium (mg/day)	2280.3 (904.4)	-457.90 (1041.31)	-0.57	-500.86 (1091.13)	-0.58	2168.1 (676.3)	-212.97 (685.70)	-0.33	-111.46 (887.59)	-0.08

6wk = 6 weeks; 12wk = 12 weeks. At 6 weeks, intervention N=29, control N=29. At 12 weeks, intervention N=29, control N=26.
EI = energy intake; CHO = carbohydrate; kcal/day = calories per day; g/day = grams per day.
Positive effect sizes indicate an increase in the variable over time, negative effect sizes indicate a decrease over time. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Table 5.6 ANCOVA results (F), adjusted mean differences between the intervention and control groups, and effect sizes for dietary intake at 6 and 12 weeks

	6 weeks			12 weeks		
	F (df = 1, 53)	AMΔ* (95% CI)	d (95% CI)	F (df = 1, 49)	AMΔ* (95% CI)	d (95% CI)
Total energy intake (kcal/day)	2.1	-198 (-473, 76)	-0.50 (-1.01, 0.03)	2.59	-214 (-481, 53)	-0.49 (-1.02, 0.05)
Total carbohydrate (g/day)	1.91	-21.80 (-53.45, 9.86)	-0.49 (-1.00, 0.04)	1.7	-21.35 (-54.31, 11.61)	-0.46 (-0.98, 0.09)
Sugar (g/day)	0.59	-4.63 (-16.76, 7.51)	-0.34 (-0.85, 0.19)	0.24	-3.73 (-18.96, 11.51)	-0.24 (-0.77, 0.30)
Fibre (g/day)	0.24	1.04 (-3.13, 5.20)	0.08 (-0.44, 0.59)	0.01	0.18 (-3.26, 3.61)	-0.03 (-0.56, 0.50)
Total fat (g/day)	5.74[1]	-15.90 (-29.22, -2.59)	-0.54 (-1.06, -0.01)	3.8[2]	-12.15 (-24.68, 0.37)	-0.38 (-0.90, 0.16)
Saturated fat (g/day)	8.34[3]	-8.83 (-14.97, -2.69)	-0.72 (-1.24, -0.17)	2.94	-4.49 (-9.75, 0.77)	-0.36 (-0.89, 0.18)
Protein (g/day)	1.62	-8.53 (-21.99, 4.94)	-0.44 (-0.96, 0.08)	0.33	-3.39 (-15.26, 8.49)	-0.30 (-0.82, 0.24)
Sodium (mg/day)	0.65	-136.16 (-474.58, 202.26)	-0.28 (-0.79, 0.24)	2.93	-339.04 (-736.92, 58.84)	-0.39 (-0.92, 0.15)

At 6 weeks, intervention N=29, control N=29. At 12 weeks, intervention N=29, control N=26.
EI = energy intake; CHO = carbohydrate; kcal/day = calories per day; g/day = grams per day.
[1]p<0.05, [2]p=0.057, [3]p<0.01
*Covariates in the model included sex, age, baseline BMI and baseline values of the dependent variable. Negative adjusted mean difference scores indicate a greater reduction was found in the intervention group than the control group.
Negative effect size indicates greater reductions in the intervention group. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Exploratory subgroup analysis of intervention effects

Post hoc correlations were conducted to explore whether the intervention or control condition had different effects depending on participants' age or baseline BMI, PAL and energy intake (results are shown in Table 5.7). For both groups, age was not associated with any of the primary outcome measures (12 week change scores for PA and dietary parameters). Baseline BMI was also not significantly correlated with any of the primary PA outcomes for either group. In the intervention group, baseline BMI was negatively associated with change in total energy intake and sugar intake at 12 weeks; in the control group, baseline BMI was not associated with any dietary outcome. Baseline PAL was not associated with 12-week changes in any of the PA outcomes. In contrast, among the control group, baseline PAL was significantly negatively associated changes in PAL, moderate intensity activity, MVPA, TEE and daily steps, and positively associated with changes in sedentary time. This suggests that those who were more active when they entered the study were less likely than those who were relatively inactive at baseline to increase their activity, if they were in the control condition; the intervention condition had similar effects on PA regardless of baseline PAL. In the intervention group, baseline energy intake was negatively associated with 1- week change in total energy, carbohydrate, sugar, fat, saturated fat, protein and sodium intakes. In the control group, baseline energy intake was also negatively associated with 12-week change in total energy, carbohydrate, fat and saturated fat intakes. This suggests that for both groups, but to a greater extent among those in the intervention group, people who consumed more at baseline were more likely to have made greater reductions in their dietary intake over the course of the study.

Independent t-tests were conducted to compare primary outcomes between males and females: no significant differences for either group were found.

Table 5.7 Correlations between intervention group baseline characteristics and primary outcome measures (12-week change scores for physical activity and dietary parameters)

	Intervention				Control			
	Baseline PAL	Baseline EI	Age	Baseline BMI	Baseline PAL	Baseline EI	Age	Baseline BMI
Baseline PAL		0.13	0.05	-0.22		0.10	-0.13	-0.02
Baseline EI			-0.12	0.30			-0.04	0.16
Age				-0.36*				0.20
Daily PAL (TEE/BMR)	-0.09		0.07	0.09	-0.47*		-0.24	-0.21
Sedentary (min/day)	0.12		0.01	-0.13	0.48**		0.18	0.08
Light (min/day)	-0.07		-0.08	0.12	-0.07		-0.08	0.03
Moderate (min/day)	-0.16		0.02	0.09	-0.52**		-0.10	-0.08
Vigorous (min/day)	0.03		0.07	0.03	-0.21		-0.27	-0.08
MVPA (min/day)	-0.11		0.05	0.08	-0.52**		-0.17	-0.10
TEE (kcal)	-0.21		0.02	0.16	-0.55**		-0.13	-0.17
Daily steps	0.21		0.23	0.08	-0.62**		-0.06	-0.17
Total EI (kcal/day)		-0.77**	0.21	-0.41*		-0.43*	0.10	0.05
Total CHO (g/day)		-0.59**	0.19	-0.36		-0.39*	0.74	-0.13
Sugar (g/day)		-0.45*	0.26	-0.54**		-0.01	-0.01	-0.14
Fibre (g/day)		-0.32	0.03	-0.30		-0.13	0.26	0.10
Total fat (g/day)		-0.71**	0.22	-0.30		-0.45*	0.05	0.06
Saturated fat (g/day)		-0.75**	0.10	-0.25		-0.55*	-0.16	-0.10
Protein (g/day)		-0.45*	0.24	-0.36		-0.18	0.30	0.11
Sodium (mg/day)		-0.47**	-0.02	-0.01		-0.26	0.06	0.12

*p < 0.05, **p < 0.01 PAL = physical activity level; TEE = total energy expenditure; BMR = basal metabolic rate; MVPA = moderate to vigorous PA; min/day = minutes per day; EI = energy intake; CHO = carbohydrate; kcal/day = calories per day; g/day = grams per day. N.B. A positive change score indicates an increase in the parameter from baseline to 12 weeks.

5.3.4 Health markers

Change in anthropometric and blood biomarker parameters over the course of the study, for each group, are displayed in Table 5.8. ANCOVA results for health markers are shown in Table 5.9. The differences between groups' 12-week change scores for body mass, BMI and waist circumference were of small effect size but did not reach significance, with the intervention group having slightly greater reductions (Body mass: AMΔ = -0.62kg, 95% CI = -2.28 to 1.05, d = -0.28. BMI: AMΔ = -0.23, 95% CI = -0.74 to 0.27, d = -0.25. WC: AMΔ = -1.3cm, 95% CI = -3.3 to 0.7, d = -0.37). Differences of small effect size between the groups' change scores were also found for total cholesterol and glucose levels; for glucose, this difference reached significance and reflected less positive results for the control group (Total cholesterol: AMΔ = -0.24mmol/L, 95% CI = -0.59 to 0.11, d = -0.26. Glucose: AMΔ = -0.22mmol/L, 95% CI = -0.46 to 0.01, $F(1,52) = 3.67$, $p < 0.05$, d = -0.36). As can be seen from Table 5.8, there were no meaningful changes in any of the blood biomarkers for the intervention group at 12 weeks but in the control group increases of small effect size were found in glucose, total and LDL cholesterol.

At 12 weeks the intervention group had made meaningful reductions in waist circumference (M(SD) change = -2.9 (4.2)cm, d = -0.30), systolic blood pressure (M(SD) change = -4 (9)mmHg, d = -0.67) and diastolic blood pressure (M(SD) change = -3 (6)mmHg, d = -0.40). Reductions in blood pressure were also found in the control group (Systolic BP: M(SD) change = -4 (9)mmHg, d = -0.28; diastolic BP: (M(SD) change = -3 (6)mmHg, d = -0.37). In both groups, the reductions in systolic and diastolic blood pressure were of clinically meaningful magnitude: reductions of 2mmHg or more can significantly reduce the incidence of cardiovascular disorders in both hypertensive and normotensive individuals (BPLTT Collaboration, 2003; Wong & Wright, 2014).

Table 5.8 Mean (SD) baseline, 6-week change and 12-week change scores, and effect sizes (d) for health markers in the intervention and control groups

	Intervention					Control				
	Baseline	6wk change	d 6wk change	12wk change	d 12wk change	Baseline	6wk change	d 6wk change	12wk change	d 12wk change
Body mass (kg)	91.93 (15.13)	-1.32 (2.40)	-0.09	-2.03 (3.78)	-0.14	88.64 (10.98)	-0.57 (1.49)	-0.05	-1.18 (2.16)	-0.11
BMI (kg/m^2)	30.26 (4.21)	-0.41 (0.76)	-0.10	-0.64 (1.18)	-0.15	30.28 (3.02)	-0.18 (0.50)	-0.06	-0.4 (0.71)	-0.13
WC (cm)	104.8 (9.5)	-2.2 (3.2)	-0.23	-2.9 (4.2)	-0.30	103.8 (8.6)	-1.0 (3.4)	-0.12	-1.5 (3.7)	-0.17
Systolic BP (mmHg)	134.3 (9.4)	-3.7 (10.7)	-0.31	-4.7 (9.7)	-0.67	132.9 (13.8)	-0.8 (10.2)	0.02	-4.4 (8.9)	-0.28
Diastolic BP (mmHg)	88.4 (7.2)	-2.0 (8.7)	-0.27	-2.5 (6.4)	-0.40	89.1 (9.1)	-2.5 (4.1)	-0.27	-3.2 (6.1)	-0.37
CRP (mg/L)	2.09 (1.92)	-0.02 (2.31)	-0.02	-0.03 (1.75)	-0.02	2.06 (1.49)	0.23 (2.36)	0.13	0.22 (1.37)	0.14
Triglycerides (mmol/L)	1.26 (0.48)	-0.11 (0.37)	-0.25	-0.05 (0.39)	-0.10	1.45 (0.90)	0.02 (0.81)	0.02	0.06 (0.71)	0.05
Total cholesterol (mmol/L)	5.06 (1.24)	-0.11 (0.60)	-0.10	-0.02 (0.58)	-0.02	5.02 (1.12)	0.17 (0.55)	0.15	0.23 (0.76)	0.19
HDL cholesterol (mmol/L)	1.31 (0.52)	-0.04 (0.28)	-0.08	-0.06 (0.30)	-0.15	1.23 (0.34)	0.02 (0.12)	0.03	0.02 (0.26)	0.03
LDL cholesterol (mmol/L)	3.18 (1.06)	-0.02 (0.47)	-0.03	0.06 (0.46)	0.06	3.13 (0.93)	0.14 (0.54)	0.16	0.19 (0.60)	0.20
Glucose (mmol/L)	5.75 (1.02)	-0.07 (0.52)	-0.07	0.02 (0.56)	0.02	5.60 (0.50)	0.14 (0.48)	0.24	0.30 (0.44)	0.54
Insulin µU/L)	10.72 (5.30)	-0.86 (4.97)	-0.16	-0.77 (5.35)	-0.16	9.53 (4.8)	0.17 (2.99)	0.03	-0.61 (2.27)	-0.12
HOMA-IR	2.72 (1.39)	-0.21 (1.23)	-0.14	-0.14 (1.17)	-0.11	2.39 (1.33)	0.16 (0.94)	0.11	-0.01 (0.70)	-0.01

kg = kilograms, BMI = body mass index, kg/m^2 = kilograms per metre squared, WC = waist circumference, cm = centimetres, BP = blood pressure, mmol/L = millimoles per litre, CRP = C-reactive protein, µU/L = micro units per litre, HOMA-IR = homeostasis model assessment for insulin resistance.

For systolic and diastolic BP, analyses excluded two participants (one in each group) who started new blood pressure controlling medication mid-study, thus Evolife N=29 and Control N=28 for systolic and diastolic BP. For other anthropometric data, intervention N=30, control N=29 at all time points. For blood parameters (CRP to HOMA-IR), intervention N=29, control N=28.

Positive effect sizes indicate an increase in the variable over time, negative effect sizes indicate a decrease over time. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Healthy reference levels for blood markers: CRP < 1mg/L, triglycerides < 1.7mmol/L, total cholesterol < 5mmol/L, LDL cholesterol < 3mmol/L, HDL cholesterol > 1mmol/L, glucose ≤ 5.6 mmol/L

Table 5.9 ANCOVA results (F), adjusted mean differences between the intervention and control groups, and effect sizes for health markers at 6 and 12 weeks

	6 weeks			12 weeks		
	F (df = 1, 53)	AMΔ* (95% CI)	d (95% CI)	F (df = 1, 53)	AMΔ* (95% CI)	d (95% CI)
Body mass (kg)	1.14	-0.55 (-1.58, 0.48)	-0.38 (-0.88, 0.15)	0.56	-0.62 (-2.28, 1.05)	-0.28 (-0.78, 0.24)
BMI (kg/m^2)	1.88	-0.22 (-0.55, 0.10)	-0.36 (-0.87, 0.16)	0.86	-0.23 (-0.74, 0.27)	-0.25 (-0.75, 0.27)
WC (cm)	1.91	-1.13 (-2.76, 0.51)	-0.38 (-0.89, 0.14)	1.69	-1.31 (-3.33, 0.71)	-0.37 (-0.88, 0.15)
Systolic BP (mmHg)	1.06	-2.49 (-7.34, 2.36)	-0.28 (-0.80, 0.25)	0.01	0.22 (-4.21, 4.66)	-0.03 (-0.55, 0.49)
Diastolic BP (mmHg)	<0.01	0.03 (-3.23, 3.29)	0.06 (-0.46, 0.58)	0.03	0.23 (-2.37, 2.83)	0.11 (-0.41, 0.63)
CRP (mg/L)	0.31	-0.30 (-1.38, 0.78)	-0.11 (-0.62, 0.41)	0.33	-0.22 (-0.98, 0.55)	-0.15 (-0.67, 0.36)
Triglycerides (mmol/L)	0.84	-0.15 (-0.49, 0.18)	-0.21 (-0.72, 0.31)	0.49	-0.11 (-0.41, 0.20)	-0.12 (-0.71, 0.33)
Total cholesterol (mmol/L)	3.66 [a]	-0.27 (-0.56, 0.01)	-0.49 (-1.00, 0.04)	1.86	-0.24 (-0.59, 0.11)	-0.26 (-0.88, 0.15)
HDL cholesterol (mmol/L)	0.39	-0.03 (-0.14, 0.07)	-0.28 (-0.79, 0.24)	0.69	-0.05 (-0.18, 0.07)	-0.14 (-0.80, 0.24)
LDL cholesterol (mmol/L)	1.53	-0.16 (-0.41, 0.10)	-0.32 (-0.83, 0.21)	0.73	-0.12 (-0.40, 0.16)	-0.15 (-0.76, 0.28)
Glucose (mmol/L)	1.53	-0.15 (-0.40, 0.10)	-0.42 (-0.93, 0.11)	3.67[a]	-0.22 (-0.46, 0.01)	-0.36 (-1.07, -0.02)
Insulin µU/L)	0.24	-0.51 (-2.59, 1.57)	-0.25 (-0.76, 0.27)	0.25	0.49 (-1.47, 2.44)	-0.04 (-0.55, 0.48)
HOMA-IR	0.83	-0.26 (-0.84, 0.32)	-0.34 (-0.85, 0.18)	0.002	-0.01 (-0.50, 0.49)	-0.11 (-0.65, 0.38)

kg = kilograms, BMI = body mass index, kg/m^2 = kilograms per metre squared, WC = waist circumference, cm = centimetres, BP = blood pressure, mmol/L = millimoles per litre, CRP = C-reactive protein, µU/L = micro units per litre, HOMA-IR = homeostasis model assessment for insulin resistance.

*Covariates in the model included sex, age, baseline BMI and baseline values of the dependent variable. Negative adjusted mean difference scores indicate a greater reduction was found in the intervention group than the control group.

For systolic and diastolic BP, analyses excluded two participants (one in each group) who started new blood pressure controlling medication mid-study, thus Evolife N=29 and Control N=28, DF=1,51 for systolic and diastolic BP.

Negative effect size indicates greater reductions in the intervention group, except for glucose and LDL cholesterol as levels of these increased for both groups so negative effect sizes indicate less increase in the intervention group. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

[a]p = 0.06

5.3.5 Process evaluation

All questionnaire scales demonstrated acceptable internal consistency at all three time points (Cronbach's $\alpha > 0.7$) except for the self-monitoring scale for diet at baseline ($\alpha = 0.5$). As the scale had acceptable consistency at 6 and 12 weeks ($\alpha = 0.7$ and 0.8, respectively) it was retained in the analysis.

5.3.5.1 Effect on motivation and self-efficacy

It was hypothesised that the intervention would lead to increases in autonomous motivation and self-efficacy for PA and consuming a healthy diet. Baseline, 6-week and 12-week change scores for each groups' motivation and self-efficacy are displayed in Table 5.10 and the ANCOVA results, adjusted mean differences between the intervention and control groups and effect sizes are shown in Table 5.11. Differences of small effect size that did not reach significance were found between groups' 12-week change scores for autonomous motivation and self-efficacy for PA and autonomous motivation for consuming a healthy diet, indicating slightly greater increases for the intervention group (PA: autonomous motivation AMΔ = 0.12, 95% CI = -0.15 to 0.39, d = 0.27; self-efficacy AMΔ = 2.66, 95% CI = -4.46 to 9.79, d = 0.22. Diet: autonomous motivation AMΔ = 0.23, 95% CI = -0.07 to 0.53, d = 0.31). In the intervention group, increases of small to medium effect size, were found in autonomous motivation for PA and diet, and self-efficacy for diet (Table 5.10). Autonomous motivation and self-efficacy only increased for diet, not activity, in the control group and these increases did not reach significance. Controlled motivation did not change for either group.

Table 5.10 Mean (SD) baseline, 6-week change and 12-week change scores, and effect sizes (d) for motivation and self-efficacy, and self-regulatory behaviours in the intervention and control groups

	Intervention					Control				
	Baseline	6wk change	d 6wk change	12wk change	d 12wk change	Baseline	6wk change	d 6wk change	12wk change	d 12wk change
Controlled motivation PA (0-4)	1.6 (0.66)	0.02 (0.48)	0.05	-0.07 (0.59)	-0.10	1.55 (0.67)	0.11 (0.66)	0.16	0.01 (0.59)	0.02
Autonomous motivation PA (0-4)	2.49 (0.81)	0.24 (0.53)	0.31	0.26 (0.50)	0.29	2.64 (0.82)	0.09 (0.58)	0.11	0.12 (0.55)	0.15
Self-efficacy PA (0-100)	48.25 (17.11)	5.77 (17.18)	0.28	2.94 (13.90)	0.14	49.42 (21.42)	-1.21 (15.08)	-0.09	-0.22 (14.65)	-0.05
Action planning PA (1-5)	2.04 (1.04)	1.24 (0.98)	1.41	1.25 (0.97)	1.40	2.33 (1.05)	0.31 (1.17)	0.31	0.35 (1.00)	0.34
Coping planning PA (1-5)	1.67 (0.65)	0.99 (0.87)	1.28	1.00 (1.03)	1.29	1.85 (0.87)	0.13 (0.94)	0.14	0.38 (0.86)	0.41
Self-monitoring PA (1-4)	2.15 (0.52)	0.97 (0.72)	1.86	0.90 (0.72)	1.68	2.41 (0.62)	0.20 (0.55)	0.35	0.34 (0.64)	0.51
Social support PA (1-5)	2.23 (1.05)	0.02 (0.83)	0.02	-0.13 (0.62)	-0.13	2.39 (1.10)	-0.14 (0.92)	-0.11	-0.08 (0.63)	-0.07
Habit PA (1-7)	2.74 (1.57)	0.70 (1.82)	0.47	1.09 (1.50)	0.71	3.50 (1.42)	0.44 (1.24)	0.30	0.59 (1.26)	0.39
Controlled motivation diet (0-4)	1.64 (0.71)	-0.02 (0.50)	0.03	<0.01 (0.76)	0.07	1.78 (0.73)	-0.12 (0.50)	-0.14	-0.04 (0.44)	-0.04
Autonomous motivation diet (0-4)	2.46 (0.65)	0.35 (0.45)	0.50	0.38 (0.49)	0.56	2.39 (0.69)	0.10 (0.63)	0.15	0.19 (0.70)	0.28
Self-efficacy diet (1-5)	3.44 (0.48)	0.17 (0.40)	0.40	0.26 (0.55)	0.45	3.33 (0.69)	0.14 (0.55)	0.15	0.14 (0.68)	0.24
Action planning diet (1-5)	2.13 (0.83)	1.13 (0.97)	1.63	0.99 (1.05)	1.38	2.49 (0.84)	0.49 (0.86)	0.63	0.39 (0.86)	0.50
Coping planning diet (1-5)	1.73 (0.63)	0.60 (0.94)	0.80	0.57 (0.86)	0.86	1.86 (0.72)	0.43 (0.66)	0.61	0.43 (0.89)	0.55
Self-monitoring diet (1-4)	2.35 (0.45)	0.59 (0.58)	1.29	0.51 (0.62)	0.98	2.37 (0.44)	0.24 (0.42)	0.56	0.33 (0.60)	0.68
Social support diet (1-5)	3.08 (0.85)	0.11 (0.72)	0.08	0.06 (0.77)	0.04	3.04 (0.90)	0.28 (0.70)	0.34	0.07 (0.69)	0.18
Habit diet (1-7)	3.46 (1.45)	0.49 (0.99)	0.34	0.72 (1.23)	0.46	3.24 (1.57)	0.43 (1.22)	0.30	0.60 (1.18)	0.40

PA = physical activity. 6wk = 6 weeks; 12wk = 12 weeks. At 6 weeks, intervention N=30, control N=29. At 12 weeks, intervention N=30, control N=29.

Positive effect sizes indicate an increase in the variable over time, negative effect sizes indicate a decrease over time. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

Table 5.11 ANCOVA results (F), adjusted mean differences between the intervention and control groups, and effect sizes for motivation and self-efficacy, and self-regulatory behaviours at 6 and 12 weeks

	6 weeks			12 weeks		
	F (df = 1, 53)	AMΔ* (95% CI)	d (95% CI)	F (df = 1, 53)	AMΔ* (95% CI)	d (95% CI)
Controlled motivation PA	0.24	-0.07 (-0.34, 0.20)	-0.16 (-0.67, 0.36)	0.18	-0.06 (-0.34, 0.23)	-0.14 (-0.64, 0.38)
Autonomous motivation PA	0.74	0.11 (-0.15, 0.38)	0.27 (-0.25, 0.78)	0.78	0.12 (-0.15, 0.39)	0.27 (-0.25, 0.78)
Self-efficacy PA	2.39	6.04 (-1.82, 13.90)	0.43 (-0.10, 0.96)	0.56	2.66 (-4.46, 9.79)	0.22 (-0.30, 0.74)
Action planning PA	10.59	0.74 (0.28, 1.20)	0.86 (0.29, 1.41)	8.58	0.62 (0.19, 1.04)	0.91 (0.35, 1.45)
Coping planning PA	10.96	0.70 (0.28, 1.13)	0.95 (0.39, 1.49)	3.34	0.41 (-0.04, 0.85)	0.65 (0.11, 1.18)
Self-monitoring PA	18.86	0.58 (0.31, 0.85)	1.20 (0.63, 1.74)	6.61	0.40 (0.09, 0.71)	0.82 (0.28, 1.34)
Social support PA	0.13	0.08 (-0.35, 0.50)	0.18 (-0.34, 0.70)	0.37	-0.09 (-0.40, 0.21)	-0.08 (-0.59, 0.43)
Habit PA	0.18	-0.16 (-0.90, 0.58)	0.17 (-0.35, 0.68)	0.36	0.21 (-0.49, 0.91)	0.36 (-0.16, 0.87)
Controlled motivation diet	0.35	0.08 (-0.19, 0.34)	0.20 (-0.32, 0.71)	0.01	0.14 (-0.30, 0.33)	0.06 (-0.45, 0.58)
Autonomous motivation diet	4.01	0.27 (-0.001, 0.54)	0.46 (-0.07, 0.97)	2.30	0.23 (-0.07, 0.53)	0.31 (-0.21, 0.83)
Self-efficacy diet	0.40	0.08 (-0.17, 0.32)	0.06 (-0.48, 0.60)	1.21	0.15 (-0.13, 0.43)	0.19 (-0.35, 0.74)
Action planning diet	4.82	0.35 (0.03, 0.67)	0.70 (0.15, 1.22)	4.45	0.36 (0.02, 0.70)	0.63 (0.08, 1.15)
Coping planning diet	0.28	0.10 (-0.28, 0.48)	0.21 (-0.32, 0.73)	0.01	-0.02 (-0.42, 0.39)	0.16 (-0.36, 0.68)
Self-monitoring diet	8.96	0.33 (0.11, 0.54)	0.69 (0.16, 1.20)	1.15	0.15 (-0.13, 0.43)	0.30 (-0.22, 0.80)
Social support diet (1-5)	0.69	-0.15 (-0.50, 0.21)	-0.24 (-0.79, 0.32)	0.03	-0.03 (-0.39, 0.34)	-0.01 (-0.56, 0.54)
Habit diet	0.27	0.13 (-0.38, 0.64)	0.05 (-0.46, 0.56)	0.31	0.16 (-0.42, 0.75)	0.10 (-0.41, 0.61)

Positive effect sizes indicate a greater increase in the intervention group. Negative effect size indicates greater reductions in the intervention group (controlled motivation) or a greater increase in the control group. Small effect: d = 0.20 – 0.49; medium effect: d = 0.50 – 0.79; large effect: d = 0.80+.

5.3.5.2 Effect on self-regulatory behaviours

The intervention was predicted to promote self-regulating behaviours (action planning, coping planning and self-monitoring) for PA and consuming a healthy diet. At 12 weeks, the intervention group had increased their self-monitoring of PA and action planning for both PA and diet to a significantly greater extent than the control group, after adjusting for baseline scores; the difference between groups' change scores were of medium to large effect size (Table 5.11). Relative to the control group, the intervention group had also made greater increases, of small and medium effect size, in self-monitoring of diet and coping planning for PA, respectively; however, the differences between groups for these two variables did not reach significance. The ANCOVA results reflect the increases, of large effect size, found in the intervention group at 6 weeks and sustained to 12 weeks for action planning, coping planning and self-monitoring for both PA and diet (Table 5.10). At 12 weeks, the control group had also made meaningful changes in action planning, coping planning and self-monitoring for both PA and diet, but these were of smaller magnitude.

5.3.5.3 Do motivation and self-efficacy predict self-regulation?

To assess whether increases in autonomous motivation and self-efficacy predicted increases in self-regulatory behaviour, action planning, coping planning and self-monitoring were regressed separately on autonomous motivation and self-efficacy. Separate regressions were conducted for PA and consuming a healthy diet. Group and baseline autonomous motivation and self-efficacy scores were entered into the regression models first as covariates, and 12-week autonomous motivation and self-efficacy scores entered together in a second block. Results from the regression analyses can be found in Tables 5.12 and 5.13. Thirty-seven percent of the variance in action planning for PA was explained by the covariates in the model ($R^2 = 0.37$, $F(3,52) = 10.12$, $p < 0.01$), with each covariate significantly and positively predictive (β group = 0.37, $p < 0.01$ – i.e. those in the intervention group were more likely to engage in action planning for PA; β baseline autonomous motivation = 0.31, $p = 0.01$; β baseline self-efficacy = 0.36, $p < 0.01$). When autonomous motivation and self-efficacy for PA at 12 weeks were added to the model, predictive power did not significantly increase ($R^2 = 0.42$, $F_{change}(2,50) = 2.22$, $p > 0.05$). The covariates predicted 28% of the variance in coping planning for PA ($R^2 = 0.28$, $F(3,53) = 6.91$, $p < 0.01$); being in the intervention group was significantly predictive of increased coping planning ($\beta = 0.27$, $p = 0.03$) as was increased baseline autonomous motivation for PA ($\beta = 0.36$, $p < 0.01$). When 12 week motivation and self-efficacy were added to the model, the predictive power significantly increased to 39% ($R^2 = 0.39$, $F_{change}(2,51) = 4.43$, $p < 0.05$), with autonomous motivation at 12 weeks being independently predictive ($\beta = 0.53$, $p = 0.01$).

Twenty-four percent of the variance in self-monitoring of PA was predicted by the covariates ($R^2 = 0.24$, $F(3,53) = 5.56$, $p < 0.01$); again, being in the intervention group was significantly predictive of increased self-monitoring for PA ($\beta = 0.31$, $p = 0.01$), as was increased baseline autonomous motivation for PA ($\beta = 0.31$, $p = 0.02$). When autonomous motivation and self-efficacy at 12 weeks were added to the model the amount of variance explained significantly increased to 43% ($R^2 = 0.43$, $F_{change}(2,51) = 8.71$, $p < 0.01$), with autonomous motivation at 12 weeks being independently predictive ($\beta = 0.64$, $p < 0.01$).

Twelve percent of the variance in action planning for consuming a healthy diet was predicted by the covariates ($R^2 = 0.12$, $F(3,46) = 2.02$, $p > 0.05$), with no independently predictive variables. When autonomous motivation and self-efficacy for consuming a healthy diet were added to the model, the proportion of variance explained significantly increased to 24% ($R^2 = 0.24$, $F_{change}(2,44) = 3.51$, $p = 0.04$), again with no independently predictive variables. Only 4% of the variance in coping planning for consuming a healthy diet was predicted by the covariates ($R^2 = 0.04$, $F(3,47) = 0.06$, $p > 0.05$), with no independently predictive variables. This significantly increased to 25% when 12 week autonomous motivation and self-efficacy were added to the model ($R^2 = 0.25$, $F_{change}(2,45) = 7.44$, $p < 0.01$), with self-efficacy at 12 weeks being independently predictive ($\beta = 0.52$, $p < 0.01$). Only 3% of the variance in self-monitoring of consuming a healthy diet was predicted by the covariates ($R^2 = 0.03$, $F(3,47) = 0.50$, $p > 0.05$), with no independently predictive variables. This significantly increased to 29% when 12 week autonomous motivation and self-efficacy were added to the model ($R^2 = 0.29$, $F_{change}(2,45) = 8.10$, $p < 0.01$), again with self-efficacy at 12 weeks being independently predictive ($\beta = 0.58$, $p < 0.01$).

Table 5.12 Results for hierarchical regressions of autonomous motivation and self-efficacy on self-regulatory behaviours for physical activity in Study 3

	Model R^2	F change in R^2		B	S.E. B	β	p
Action planning for physical activity	0.37	-	Constant	0.99	0.40	-	0.02
			Group	0.66	0.20	0.37	<0.01
			Autonomous motivation baseline	0.34	0.13	0.31	0.01
			Self-efficacy baseline	0.02	0.01	0.36	<0.01
	0.42	2.22	Constant	0.95	0.39	-	0.02
			Group	0.60	0.20	0.34	<0.01
			Autonomous motivation baseline	0.29	0.20	0.27	0.15
			Self-efficacy baseline	0.01	0.01	0.12	0.45
			Autonomous motivation 12 weeks	-0.05	0.21	-0.05	0.81
			Self-efficacy 12 weeks	0.02	0.01	0.36	0.05
Coping planning for physical activity	0.28	-	Constant	0.65	0.41	-	0.12
			Group	0.46	0.20	0.27	0.03
			Autonomous motivation baseline	0.39	0.13	0.36	<0.01
			Self-efficacy baseline	0.01	0.01	0.26	0.71
	0.39	4.43*	Constant	0.48	0.39	-	0.22
			Group	0.37	0.19	0.21	0.06
			Autonomous motivation baseline	-0.07	0.20	-0.07	0.73
			Self-efficacy baseline	0.01	0.01	0.13	0.41
			Autonomous motivation 12 weeks	0.54	0.21	0.53	0.01
			Self-efficacy 12 weeks	0.003	0.01	0.07	0.71
Self-monitoring for physical activity	0.24	-	Constant	1.74	0.30	-	<0.01
			Group	0.38	0.15	0.31	0.01
			Autonomous motivation baseline	0.24	0.09	0.31	0.02
			Self-efficacy baseline	0.01	0.004	0.21	0.09
	0.43	8.71**	Constant	1.59	0.27	-	<0.01
			Group	0.29	0.13	0.23	0.04
			Autonomous motivation baseline	-0.18	0.14	-0.23	0.20
			Self-efficacy baseline	-0.001	0.01	-0.03	0.85
			Autonomous motivation 12 weeks	0.47	0.14	0.64	<0.01
			Self-efficacy 12 weeks	0.01	0.01	0.22	0.21

*p<0.05 **p<0.01

Table 5.13 Results for hierarchical regressions of autonomous motivation and self-efficacy on self-regulatory behaviours for consuming a healthy diet in Study 3

	Model R^2	F change in R^2		B	S.E. B	β	p
Action planning for consuming a healthy diet	0.12	-	Constant	1.95	0.54	-	<0.01
			Group	0.32	0.19	0.24	0.10
			Autonomous motivation baseline	-0.01	0.17	-0.01	0.94
			Self-efficacy baseline	0.27	0.17	0.24	0.13
	0.24	3.51*	Constant	1.08	0.66	-	0.11
			Group	0.21	0.18	0.15	0.27
			Autonomous motivation baseline	-0.09	0.20	-0.08	0.67
			Self-efficacy baseline	0.11	0.19	0.10	0.57
			Autonomous motivation 12 weeks	0.17	0.19	0.18	0.38
			Self-efficacy 12 weeks	0.33	0.22	0.28	0.14
Coping planning for consuming a healthy diet	0.04	-	Constant	2.21	0.67	-	<0.01
			Group	-0.03	0.23	-0.02	0.89
			Autonomous motivation baseline	-0.07	0.20	-0.06	0.74
			Self-efficacy baseline	0.07	0.21	0.06	0.73
	0.25	7.44**	Constant	0.54	0.76	-	0.48
			Group	-0.18	0.21	-0.11	0.40
			Autonomous motivation baseline	-0.07	0.23	-0.06	0.76
			Self-efficacy baseline	0.24	0.21	-0.18	0.27
			Autonomous motivation 12 weeks	0.08	0.22	0.08	0.70
			Self-efficacy 12 weeks	0.72	0.25	0.52	0.01
Self-monitoring for consuming a healthy diet	0.03	-	Constant	2.50	0.48	-	<0.01
			Group	0.18	0.16	0.16	0.27
			Autonomous motivation baseline	-0.01	0.15	-0.01	0.96
			Self-efficacy baseline	0.06	0.15	0.07	0.69
	0.29	8.10**	Constant	1.21	0.54	-	0.03
			Group	0.09	0.15	0.08	0.56
			Autonomous motivation baseline	0.04	0.16	0.04	0.82
			Self-efficacy baseline	-0.18	0.15	-0.20	0.22
			Autonomous motivation 12 weeks	-0.01	0.15	-0.01	0.96
			Self-efficacy 12 weeks	0.58	0.18	0.58	<0.01

*p<0.05 **p<0.01

5.3.5.4 Do self-regulatory behaviours mediate intervention effects on physical activity level and energy intake?

Process analyses were conducted to assess whether intervention effects on PA and energy intake were mediated by self-regulatory behaviours; results are provided in Table 5.14. The only significant indirect effect of intervention on physical activity levels was through action planning (indirect effect of group on PAL through action planning = 0.06, 95% CI = 0.01, 0.13). Exposure to the intervention directly and positively influenced action planning (effect of group on action planning = 0.74, 95% CI = 0.32, 1.16) and increased action planning was associated with higher physical activity levels (effect of action planning on PAL = 0.08, 95% CI = 0.005; 0.15) Exposure to the intervention was also associated with increased coping planning and self-monitoring for PA but these did not mediate the intervention's effect on PA (effect of group on coping planning = 0.55, 95% CI = 0.11, 0.99; effect of group on self-monitoring: a_3 = 0.44, 95% CI = 0.10, 0.77). No other direct or indirect effects were found for the PA model.

The intervention's effects on diet were not found to be mediated by any of the three self-regulatory behaviours. Exposure to the intervention did have a direct positive effect on action planning (a_4 = 0.41, 95% CI = 0.04, 0.77). None of the self-regulatory behaviours were significantly associated with energy intake at 12 weeks and there were no significant indirect effects.

Table 5.14 Mediation models for intervention effects on 12 week physical activity level (PAL) and energy intake (EI)

Model	Coefficient	S.E.	p	Bootstrap 95% CI
Intervention group to PAL via action planning, coping planning, self-monitoring (N = 54)				
Total effect	0.06	0.04	0.17	(-0.03; 0.14)
Direct effect (group on PAL)	0.02	0.04	0.70	(-0.07; 0.11)
Indirect (mediated) effects				
Group on action planning	0.74	0.21	0.001	(0.32; 1.16)
Action planning on PAL	0.08	0.04	0.04	(0.005; 0.15)
Group on coping planning	0.55	0.22	0.02	(0.11; 0.99)
Coping planning on PAL	-0.06	0.03	0.07	(-0.13; 0.01)
Group on self-monitoring	0.44	0.17	0.01	(0.10; 0.77)
Self-monitoring on PAL	0.04	0.04	0.35	(-0.04; 0.12)
Model R^2 (p)		0.63 (<0.001)		
Intervention group to EI via action planning, coping planning, self-monitoring (N = 52)				
Total effect	-272.96	143.44	0.06	(-561.70; 15.78)
Direct effect (group on EI)	-230.46	155.65	0.15	(-544.36; 83.44)
Indirect effect				
Group on action planning	0.41	0.18	0.03	(0.04; 0.77)
Action planning on EI	-125.52	157.83	0.43	(-443.82; 192.79)
Group on coping planning	0.12	0.22	0.58	(-0.32; 0.56)
Coping planning on EI	65.25	129.51	0.62	(-195.93; 326.43)
Group on self-monitoring	0.21	0.16	0.18	(-0.10; 0.53)
Self-monitoring on EI	4.58	199.38	0.98	(-397.51; 406.67)
Model R^2 (p)		0.21 (0.04)		

5.3.5.5 Do habit strength and social support additionally mediate intervention effects on physical activity level and energy intake ?

To assess whether habit strength and social support would additionally mediate the effects of the intervention on the primary outcomes, the mediation process models were run again with habit strength and social support at 12 weeks added along with the 12-week self-regulation variables. Baseline habit strength and social support were added as covariates. Habit strength at 12 weeks for PA was not found to mediate the effect of group on 12-week physical activity level (indirect effect of group on PAL through habit strength = 0.002, 95% CI = -0.04, 0.02). Group allocation did not influence 12-week habit strength for PA (effect of group on PA habit strength = 0.49, 95% CI = -0.20, 1.19) and habit strength did not directly affect PAL (effect of PA habit strength on PAL = -0.003, 95% CI = -0.04, 0.04). Social support for PA at 12 weeks also was not found to mediate the effect of group on 12 week physical activity level (indirect effect of group on PAL through social support = -0.003, 95% CI = -0.03, 0.02). Group allocation did not influence 12-week social support for PA (effect of group on PA habit strength = -0.06, 95% CI =

-0.36, 0.25) and habit strength did not directly affect PAL (effect of PA social support on PAL = 0.05, 95% CI = -0.04, 0.13).

Habit strength for consuming a healthy diet at 12 weeks was not found to mediate the effect of group on 12-week energy intake either (indirect effect of group on energy intake through habit strength = 7.09, 95% CI = -93.57, 174.79). Group allocation did not influence 12-week habit strength for consuming a healthy diet (effect of group on diet habit strength = 0.34, 95% CI = -0.31, 0.99) and habit strength did not directly affect energy intake (effect of diet habit strength on energy intake = 21.05, 95% CI = -212.94, 255.03). Social support for consuming a healthy diet at 12 weeks also was not found to mediate the effect of group on 12-week physical activity level (indirect effect of group on energy intake through social support = -0.003, 95% CI = -76.40, 68.74). Group allocation did not influence 12-week social support for energy intake (effect of group on PA habit strength = 0.01, 95% CI = -0.38, 0.40) and habit strength did not directly affect energy intake (effect of PA social support on energy intake = -0.24, 95% CI = -328.45, 327.98).

5.3.6 Interview evaluations

Of the 30 participants in the intervention group, 26 took part in an interview; the remaining four declined due to work pressures limiting their time. Interviews lasted an average of 19 minutes.

All interviewees reported that the intervention had raised their awareness of their activity levels and/or diet, and how these factors related to their health. This increased awareness seemed mainly to come from the behaviour monitoring aspects of the intervention, particularly the pedometer, but the educational information on the website was also necessary for helping participants to assess how healthy their lifestyles were:

> *[It made me] more aware of what I was eating and drinking… now that's not to say I necessarily changed many things but I was more aware. And I was more aware of not doing as much physical activity as I probably should do… the programme made me more aware of what I should be doing. (Male, 52)*

> *[I’m] more mindful of what snacks I choose, whether I'm choosing just something that's going to fill a hole or whether I'm choosing something that's going to give me some genuine nutrition. (Female, 60)*

> *I became aware of the steps I wasn't taking (laughs)... it was 2000 a day or something like that. I'd never counted it before so that was a surprise against the 10000 you should be doing, so, the first thing, it made me aware how little [activity] I was doing. (Male, 51)*

The goal setting and behaviour monitoring were highlighted as particularly useful elements of the intervention. Many participants liked having a goal to aim for, at least initially to help them form new behavioural routines:

> *I hate missing a target… so if I was going to have a target, I would do everything I can to hit it. (Male, 56)*

> *It was very good to have the goals to work towards and now that I've got that imprinted in my brain I will try and keep that going. It's just that you need something in the first place to make you make the changes. (Female, 53)*

Several participants mentioned that their previous attempts at weight-loss or behaviour change had failed after one lapse in behaviour or a bad day; the short-term nature of the goals (being able to change them on a weekly basis) in the Evolife intervention seemed to help participants overcome this:

> *I was in a routine and enjoying celebrating my successes and thinking about, okay, well it doesn't matter that I didn't do it this week, but what will I do next week… It's nice because you didn't just continue to feel like you'd failed at something because you had a new start each week. (Female, 45)*

> *I think the objective setting each week was great and the fact that you could change it each week, whereas diets in the past, you know, you do for a week then fail and then that's it, you've given up. So the fact that you've got to start again effectively [laughs], it didn't matter, that [last week] was gone, so yeah, I thought that was really effective. (Female, 40)*

A few participants highlighted that being able to choose their own goals and the effortful act of recording goals and plans on the website ("there is something about writing it down", male, 50) were helpful aspects of the intervention because the participants had to think about what would be relevant and realistic for them. However, choosing good goals proved to be a challenge:

> *It was good because you had to decide what you wanted to do… um that's also a slight downside for me… I don't know if my goals were good enough or whether I was doing the right thing. (Male, 37)*

Many participants mentioned that they would have liked more advice or suggestions on the website about possible goals to set, or feedback on whether the goals they had set were appropriate, or a forum area where website users could discuss what goals worked or didn't work for them. On the other hand, several participants also reported that although it took them a few weeks, they did eventually work out what was realistic for them.

> *I was really bad at it to start with because I just kept setting the same goals and failing each time… but then I realised that I've actually got to make changes personally or I've got to try and change the goals to hit them. (Female, 40)*

The pedometer was helpful not only for raising awareness but also for providing instant visual feedback that acted as an incentive to move more:

> *It [pedometer] jogs your memory to think 'I know I've been sat in the office most of the day and now I need to go out and get my steps up, because that's my goal'. (Male, 66)*

> *I would come to the early evening and go 'oh I've got another-' however many to do, so I would just go for a walk round the block to get the target! (Female, 43)*

Several participants mentioned that having the separate, single-function pedometer was easier than using a step-counting app on their mobile phones

> *There's one on my phone but I'd never really used it … you have to sort of physically go to it and look at it, whereas having that physical pedometer in your pocket you can pull it out and see I've only done 3000 steps, I wanted to do 10000 – I'm going to go out for a walk. (Male, 41)*

A few participants reported that they liked having a separate pedometer but, since starting the study, had bought wrist-worn pedometers or activity trackers, which they found easier to remember to wear.

Although not part of the intervention, several participants mentioned that completing the food diaries at the three assessment stages had been helpful for raising awareness of what they were eating, which in turn "pulled you back in check" (female, 43):

> *Writing it down makes you appreciate how much you're having because when you look at the list at the end of the day and you feel as if you've eaten next to nothing but there's a big list there ... because you pop something in your mouth and it's forgotten, isn't it? (Male, 51)*

The questionnaires used at the assessment visits were also mentioned by a few participants as being influential; specifically the items helped participants to consider "why you'd failed [to reach goals]" (male, 43) or to realise "that it's me that is in control" (female, 40).

Nearly all participants reported that the information on the website (e.g. about the evolutionary basis for behaviour change, physiological effects of PA, how to set SMART goals) was helpful to them in making behaviour changes. Certain facts or pieces of advice seemed to resonate with different participants:

> *For me it was the flexibility, the exercise enabling your joints to be more flexible that was a message. (Male, 61)*

> *The bit about the SMART goals being small and achievable is really important and that it's not just about eating, it's about all sorts of other things. (Female, 70)*

This in turn informed what goals they chose to set. A few participants also specifically mentioned that the narratives helped them to see what behaviour changes to make and that these could be achievable – "they were really practical, down-to-earth" (female, 51).

The majority of participants reported reading the information pages either in the first visit to the site or over the first couple of weeks of the intervention, then only using the goal recording area of the site. Those participants who did revisit the information pages (either following a prompt in the weekly email reminders or after the 6-week assessment) commented that this had helped remind them of the reasons for their behaviour change or "reinforced that what I was doing was the right thing for me" (male, 55). A few participants reported regularly revisiting the information pages throughout the study, with one woman visiting the website specifically as a motivation tactic:

> *I would go there if I want to remind myself or if I'm hungry - it's weird, 'cause if I'm hungry, I want to read something just to encourage me! (Female, 35)*

Nearly all participants reported finding the evolutionary rationale interesting, except one person saying instead that they found it "a bit simplistic". A few participants commented that the evolutionary mismatch concept was something that they were aware of before the study but the website presented the evolutionary and health information in a cohesive form that was "quite impactive… to see it there in graphics" (male, 66) and "easy to recall" (male, 57). The information was also perceived to be trustworthy:

> *There was a lot of good background information... I'm a scientist, you read something in the paper about magic pills and immediately you just go [dismissive] 'oh yeah' but when you see a coherent, whole, holistic version of the stuff about why our genes have evolved the way they have... it made a lot of sense to me. So I read it quite a lot. (Male, 51)*

While the evolutionary concept was generally felt to be helpful, the majority of participants reported that the goal setting and behaviour monitoring aspects of the intervention were the most important to them for promoting behaviour change. However, there were some participants who found the evolutionary rationale a key factor in the intervention's effectiveness:

It helps you understand. If you can understand the reasons for it, it's got to inspire you a bit more to keep to it… because if your heart's behind it, because you understand it a bit more, it makes it easier. (Male, 51)

The evolution side of things was really quite fascinating, that was particularly interesting … I'm now commuting to work on a bicycle and it's 30 miles, and people say that's crazy. But then you think well, our ancestors used to travel for miles and miles every day and it didn't do them any harm. (Female, 52)

The majority of participants stated that they probably would not continue to use the website after the study as they no longer felt the need to record their progress. Instead, many participants felt that they had formed new habits and reported that they would continue to monitor their behaviour.

Some participants experienced technical faults with the website, whereby the formatting of the goal recording page went awry when viewed on an Apple iPad or the week counter skipped forward several weeks meaning participants had to manually select the week for which they were recording goals. However, the participants experiencing these issues reported that they did not stop them using the website. Several recommendations were made as to how the intervention could be improved, one stemming from the fault with the week counter: in the goal setting area, it was felt that having calendar dates to identify the weeks (as opposed to generic 'week 1', 'week 2' etc.) would have been helpful. This would also help participants to link their performance to life events (e.g. That was the week we had a work conference and I wasn't able to get out for walks at lunch time). Some participants thought that having a weekly step target as well as a daily step target, or being able to set a different target for different days of the week, would have been better as they sometimes struggled to meet their daily target on work days but would more than compensate for this on their days off. Not reaching their daily target every day (and thus not receiving a green mark on the goal chart) was felt to be demotivating and unfair. Some participants felt that a diet recording area (similar to the food diaries) on the website would have been helpful, although they acknowledged that this would be unfeasible to complete every day.

As previously mentioned, many participants wanted more advice or suggestions on what goals to set and for links to this information to be placed on the goal setting page. A couple of participants specifically wanted more narratives to illustrate goal setting. Some participants also wanted the informational pages to be updated, for example with links to relevant news stories; it was thought that this would encourage people to return to the informational pages of the website more often. Conversely, other participants felt that the information already on the site was sufficient and that, if they wanted to know more, they could search for information on the internet. All pages on the website contained several links to other pages and some participants mentioned that they 'got lost' following links. Therefore they felt a site map or intelligent tracking system to tell people which pages they had already visited would be helpful.

Finally, one participant was colour blind and pointed out that the red, amber and green coding system on the goal recording page all looked the same colour to him.

5.4 Discussion

This study aimed to evaluate the effectiveness of an evolutionary-framed, self-directed intervention that was designed to promote increases in physical activity levels and reductions in energy intake among overweight and obese men and women aged 35 to 74 years. The study also sought to examine whether any changes in activity or diet brought about by the 12 week intervention were sufficient to generate clinically meaningful changes in metabolic control or anthropometric risk markers for developing T2DM and CVD. The intervention led to a small but meaningful improvement in physical activity level and large reductions in energy intake. Although these changes were not significantly greater than the changes made by the control group, the differences between groups were still of meaningful effect size and indicated more improvement in the intervention group. Small but meaningful changes in the intended directions were also made by the intervention group for time spent sedentary and in light and vigorous intensity activities, and daily step counts. In contrast, the control group had not made changes of meaningful effect size in any PA variables after 12 weeks. The intervention group made reductions of medium to large effect in carbohydrate, sugar, total fat, saturated fat and salt intake over the course of the study. Although these changes were greater than those made by the control group (who made reductions of small effect size in carbohydrate, sugar and saturated fat intake), the difference between groups was only significant for total fat intake.

Participants who received the intervention achieved an average loss in body mass of just over 2kg by 12 weeks; this represents a clinically meaningful reduction sufficient to decrease an individual's risk of T2DM and CVD (Greaves et al., 2015). The intervention group also made reductions of meaningful effect size in waist circumference, diastolic and systolic blood pressure. The control group unexpectedly also achieved reductions in blood pressure that could be deemed clinically meaningful, although they were not as great as the reductions made by the intervention group. Despite these physiological changes, none of the blood risk markers were found to have decreased in the intervention group. However, it is encouraging that the blood markers did not increase over the course of the study: the intervention appeared to prevent the rise in blood glucose levels that occurred in the control group.

In relation to other intervention studies, the results of this trial are promising. For example, the effect sizes found for the relative change in PA variables were larger than the overall effect size reported by Davies and colleagues (2012) in a meta-analysis of the effectiveness of Internet-delivered interventions on PA (d = 0.14). The effect sizes for both PA and dietary intake were similar to (or slightly larger than) the overall effect size found in a meta-regression of cognitive-behavioural interventions for activity and healthy eating (d = 0.31; Michie et al., 2009). In terms of minutes spent active, the intervention produced a similar relative increase to that found in a systematic review of reviews which included interventions targeting PA and/or diet, delivered face-to-face by trained providers (increase of 30-60 minutes per week; Greaves et al., 2011).

To elucidate the mechanisms through which the intervention exerted effects on behaviour, a hypothesised process model of behavioural determinants was tested. The intervention led to small but meaningful increases in autonomous motivation and self-efficacy, and these were associated, as predicted, with the large increases found in self-regulatory behaviours. However, the intervention's effects on PA and diet did not seem to be mediated through self-regulation (except for action planning of PA). These findings go against a large amount of research that has found strong, positive associations between self-regulation and PA and dietary behaviour change (Bélanger-Gravel et al., 2013; Burke et al., 2011; Laitner et al., 2016) as well as the perceptions of participants in this study, who generally reported the goal setting, planning and self-monitoring aspects of the intervention to have been the most important in helping them make changes. The small sample size, combined with the increases in self-regulation made by the control group, possibly go some way to explaining the lack of a mediating effect. Although the increases in self-regulatory behaviours made by the control group were not as great as the increases found in the intervention group, they were still of small to medium effect size. This possibly reflects the impact of being observed or measured as part of the study - phenomena known as the Hawthorne effect and measurement reactivity, respectively (Waters, Reeves, Fjeldsoe & Eakin, 2012). It is not uncommon for participants in control groups of behavioural intervention trials to change over the course of the study; Waters and colleagues (2012) have examined this in a systematic review of PA interventions. Longer trial length, more interim assessments, assessments being conducted by a researcher (rather than self-administered), and having participants who were at risk of disease (as opposed to not at risk) and with an overweight baseline BMI were all associated with finding meaningful control group improvements (Waters et al., 2012). Although the present trial was not very long (many lifestyle intervention trials last 6 months or more), participants were tested every six weeks by a researcher and they were all overweight and aware that this put them at heightened risk of disease. Furthermore, all participants volunteered for this study (as opposed to being referred by a health practitioner) which implies a reasonable degree of motivation to change that, along with being accepted onto a trial and measured regularly by another person, may have been sufficient impetus to change. Indeed, some intervention group participants mentioned in their interviews that knowing they would have to come in for assessments and being reminded of their control over their own behaviour by the questionnaires was helpful to them in making behavioural changes.

The intervention was not successful at helping participants enlist support from their friends, colleagues and relatives: social support was not found to change for either PA or consuming a healthy diet. This could help explain why social support was not found to mediate the effect of the intervention on activity or energy intake. A page of the intervention website ('The social group and you') was dedicated to coping with social situations when trying to make behaviour changes, including advice about mobilising support from others. However, interactive techniques might have been more effective at promoting social support for participants. For example, as suggested by a few participants, including a forum area on the website that allows participants to exchange ideas and discuss their experiences could help to foster a sense of community and support among users. Forum areas have been associated with increased effectiveness of online weight loss interventions (Kohl et al., 2013) and qualitative studies have found them to provide a valuable source of encouragement, emotional support and information both for active contributors and passive readers of the forum (Ballantine & Stephenson, 2011; Hwang et al., 2010). However, online forums can be problematic; for example, without the visual and oral cues of face-to-face communication, posted comments can be interpreted negatively and users may also post inaccurate information. Forums can be monitored and moderated by the intervention providers but this could entail a significant investment of time, thus increasing costs.

Meaningful increases in habit strength were found, particularly for PA, among the intervention group. This finding was supported by the interviews, in which many intervention participants reported that they felt they had now formed new habits. However, the control group also made meaningful improvements in habit strength (albeit of smaller size than the intervention group) and habit was not found to mediate the effect of the intervention on behaviour. This again might be due to measurement reactivity; after 12 weeks of being regularly assessed, and increasing their self-regulation, even the control group participants may have formed new habits. It is worth bearing in mind also that all participants entered the study based on their desire to change and so it is possible that at the start of the study they were trying out new regimes that by 12 weeks had become habits. The substantial increases in habit strength are noteworthy given the relatively short length of the study; since behaviour change is often a process of trial and error, it is unlikely that participants would have tried a new behaviour on day 1 and stuck with it for the rest of the study. Indeed intervention participants were encouraged to make small changes and gradually increase their goals over time. The findings therefore lend support to those of Lally and colleagues (2010) that habit formation can take place over a few weeks for certain behaviours and individuals.

A strength of this study was the qualitative evaluation that enabled exploration of participants' perceptions of, and experiences with, the intervention. Overall, the Evolife intervention was well received, with all participants feeling that they had positively gained from engaging with the intervention. That the goal setting, planning and self-monitoring elements of the intervention were perceived as the most helpful by the majority of participants supports the findings of several reviews and meta-analyses which have found these self-regulatory techniques to be strongly associated with PA and dietary behaviour change (Greaves et al., 2011; Michie et al., 2009; Webb et al., 2010). Self-regulatory techniques are seen as acting in a post-motivational phase of behaviour change, helping to translate motivation into action (Nurmi et al., 2016). However, it is worth noting that all intervention participants highlighted the usefulness of self-monitoring for raising awareness of their current activity and diet, which in turn seemed to act as a motivator for making changes and striving towards goals. This emphasises the complex nature of behaviour change and maintenance, whereby feedback loops seem to exist between theorised stages of change (Laitner et al., 2016). Encouragingly, participants reported that monitoring their behaviour was something that they would continue to do, whether or not they recorded their progress; a recent analysis of a behavioural weight loss intervention (involving both PA and dietary strategies) found that those participants who continued to self-monitor after the six month intervention were more successful at maintaining their weight loss over the following year (Laitner et al., 2016). With regards to the improvements in physical activity behaviour seen in the intervention group, it cannot be ruled out that the 'active ingredient' of the intervention was the pedometer. Pedometers have shown good effectiveness as behaviour change tools (Harris et al., 2017). However, participants also valued the educational content of the intervention, which again seemed to enhance their motivation. Although information provision in isolation is rarely sufficient to promote behaviour change and, as an intervention technique, it has not been found to be strongly associated with behaviour (Greaves et al., 2011; Robertson, 2008), the participant evaluations in the current study and the findings from Study 2 highlight the importance of information for increasing autonomous motivation for behaviour. Overall, the current study lends support to the proposal of Teixeira and colleagues (2011) that interventions need to target both the motivational and implemental phases of behaviour change.

An interesting finding from the evaluations was the particular value of setting short-term behavioural goals each week. Many participants had previously worked towards long-term outcome goals, such as a target weight, and several still had outcome goals while taking part in the intervention, but the ability to start afresh each week helped diminish the negative consequences of behavioural lapses. Setting behavioural goals focused participants on *how* they would reach a desired outcome, which previously they had thought about less. Both behavioural and outcome goal setting are recognised behaviour change techniques (Michie et al., 2013) but this study's findings would suggest that the former may be more effective. A further interesting finding, with implications for future interventions, is that a simple pedometer was preferred by the sample of 35-74 year olds rather than a smartphone app with step counting capability. Although apps may have more functions designed to improve health, the simplicity of the pedometers and the ease with which their data could be accessed was valued by participants.

Several suggestions were made about how the intervention could be made more engaging, which in turn might improve its effectiveness (Short et al., 2015). Updating the website and adding links to relevant news stories could help to maintain users' interest. A systematic review of Internet-delivered health promotion interventions by Brouwer and colleagues (2011) found that website updates were associated with increased exposure (i.e. more visits made to website pages). The evolutionary mismatch concept was found to be interesting by participants and seemed to help make the health messages more meaningful for many, supporting the findings from Study 1. However, it was not sufficient to sustain interest for most participants, who rarely if ever revisited the information pages. Weekly email reminders to visit the website were sent for the first six weeks of the intervention and, after three weeks, these contained prompts to look back at the information pages. These prompts were not effective for all participants, possibly because they did not see the value in re-reading something that they had read only a few weeks ago. Adding fresh information regularly to the website could help retain novelty in the intervention and thus maintain interest (Silvia, 2005, 2006). However, as with including a peer support function (such as a discussion forum), updating a website requires greater resource investment and thus costs. Future studies could investigate the optimum frequency of updating website content for sustaining users' engagement. For example, daily updates may be seen as annoying or overwhelming, especially if accompanied by emails alerting users to the updated content, but monthly updates might be welcomed and act as a helpful reminder to continue to think about one's health. If fairly infrequent (e.g. quarterly) updates are found to be sufficient to sustain engagement, this might present an acceptably cost-effective way to maintain an intervention.

As well as enabling an exploration of participants' experience with the intervention, the post-trial interviews provided a self-report measure of adherence, with all participants saying that they had used the website at least once per week throughout the 12-week study period and that after the first few weeks most people had tended to only visit the goal recording page. Gaining a more objective assessment of website use with analytic software (specifically Hotjar, 2017) had been intended; however, this software stopped working at several points throughout the study and did not consistently allow the identification of individual participants. The data Hotjar provided were thus deemed incomplete and unreliable, meaning that it was not possible to look at associations between participants' website use (and thus which behaviour change techniques they were most exposed to) and cognitive or behavioural outcomes. Google Analytics software (Google Inc., 2017) was also used and, although this could not give individual level data either, provided information on when the website had been visited and which pages were most viewed. These data corroborated participants' self-reports, showing that the website had been visited each week throughout the trial and that the most visited page was 'Keeping track', the goal recording page. Future research involving digital interventions should ensure intervention usage is measured accurately to enable assessment of adherence and exploration which aspects of the intervention were more or less effective.

The results from this study suggest that the Evolife intervention could be a promising means of promoting PA and healthy eating among overweight and obese adults aged 35 to 74 years and ways to potentially improve the intervention's effectiveness have also been identified. The small sample size and lack of long-term follow-up mean that the results should be interpreted with caution; further studies are needed to examine whether the observed behavioural changes are maintained and to test whether the intervention is effective for a wider sample. Additional resources may need to be added to the intervention to support maintenance of behaviour change as it is recognised that different techniques are required for sustaining behaviour than for initial change (Kwasnicka et al., 2016; Sniehotta, Simpson, et al., 2014).

Evolife was designed to be self-directed, offering a low-cost intervention for people at risk of developing T2DM and CVD. The participants in the current study represent a sub-section of the at-risk population as they were, to varying degrees, motivated to change their behaviour. It would be helpful to ascertain whether the intervention could be successful with other at-risk people who are less aware of their status and less motivated to change. For example, people could be recruited to the intervention via referral from their general practitioner following their NHS Health Check.

5.4.1 Conclusion

This exploratory randomised controlled trial has tested the effectiveness of an evolutionary-framed, website-based intervention at promoting increases in PA and improvements in dietary intake among overweight and obese adults. The intervention led to meaningful improvements in several cognitive and behavioural measures and the results suggest that further testing with larger, more varied samples over longer intervention and follow-up periods could be fruitful. The combination of information designed to enhance autonomous motivation and self-efficacy along with features to support self-regulatory techniques seemed to be effective and was generally well-received by participants. Potential ways to improve the intervention in terms of sustaining engagement and enhancing effectiveness were identified, which could be tested in further study.

CHAPTER 6. General discussion

In the current context of increasing prevalence of obesity and low levels of physical activity in the UK (NHS Digital, 2018), effective strategies to help people lead healthier lives are urgently needed. The research presented in this thesis aimed to develop and trial a health behaviour change intervention using the concept of an evolutionary mismatch as a framework to help overweight and inactive people understand not only *what* lifestyle factors cause disease but also *why* these factors cause disease. The concept of an evolutionary mismatch (i.e. that changes to our environment have happened too quickly for bodies to adapt) has increasingly been applied in academic health literature (Konner & Eaton, 2010; Nunn, Wallace & Beall, 2015) and some commercial diet and lifestyle programmes have been based on its basic principles; yet the mismatch concept has not been applied in public health initiatives. In Chapter 2, the evidence behind the evolutionary mismatch hypothesis was reviewed and it was shown that adopting dietary and physical activity behaviours slightly more like those of our ancestors could significantly reduce people's risk of developing non-communicable chronic disorders, such as T2DM and CVD. The second part of Chapter 2 reviewed the literature on health behaviour change and intervention design, highlighting the need to apply theory and evidence when developing and evaluating interventions in order to increase the likelihood of effectiveness and also to better understand how an intervention works. The importance of considering how an intervention's content is communicated and how well it engages the target audience was also discussed. Drawing on this varied literature, the research described in this thesis was conducted in an attempt to develop a novel and engaging behaviour change intervention using the evolutionary mismatch concept as a frame for delivering information and support. The cognitive, behavioural and health effects of the intervention were assessed to try to explore how, and how well, the intervention worked. This chapter will provide a summary of the key findings from this research, discuss the implications and consider possible directions for future research.

6.1 Summary of findings

In the first study (Chapter 3), draft mismatch-based information resources were shown to participants in interviews to explore the potential of using the concept as a framework for delivering detailed health information and also to explore the relative potential of each of the specific resources. The interviews showed that the evolutionary mismatch framework seemed to help generate interest and also seemed to provide a meaningful rationale for behaviour change. Certain graphic resources were more positively received than others and the potential for confusion and negative reactance to some text and graphics was highlighted. On the basis of these findings, and with the help of graphic designers, the resources were developed and made into booklets to be tested in the second study (Chapter 4). Specifically, Study 2 was conducted to determine whether the resources could improve understanding of the effects of physical activity and diet on health and bring about change in certain cognitive determinants of behaviour. The cognitive determinants assessed were chosen based on two relevant theories – SDT and TPB. It was posited that the evolutionary mismatch concept could provide a meaningful rationale, which would lead to increased autonomous motivation for behaviour change (see Figure 6.1), and that greater understanding of physical activity, diet and health would improve beliefs, outcome expectations, attitudes, perceived controllability, self-efficacy and intentions towards activity and healthy eating (see Figure 6.2). The mismatch framed resources were also compared with a booklet containing the same in-depth physiological information but not presented from a mismatch perspective in order to determine whether the evolutionary mismatch framework could enhance or detract from effects on understanding and cognitive change. The resources successfully enhanced understanding and brought about positive changes in most of the targeted cognitions. However, the hypothesised process models were only partially supported, with knowledge and beliefs having less influence on motivation, attitudes and intentions than anticipated. The evolutionary mismatch frame did not detract from the health messages and there were some indications, in terms of cognition change, that it provided some advantage over the non-mismatch framed resources.

Figure 6.1 Process model for the effects of exposure to the evolutionary rationale for behaviour change on behavioural intention, based on SDT

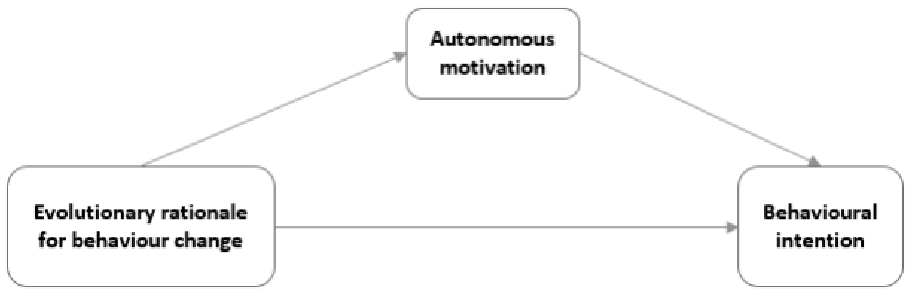
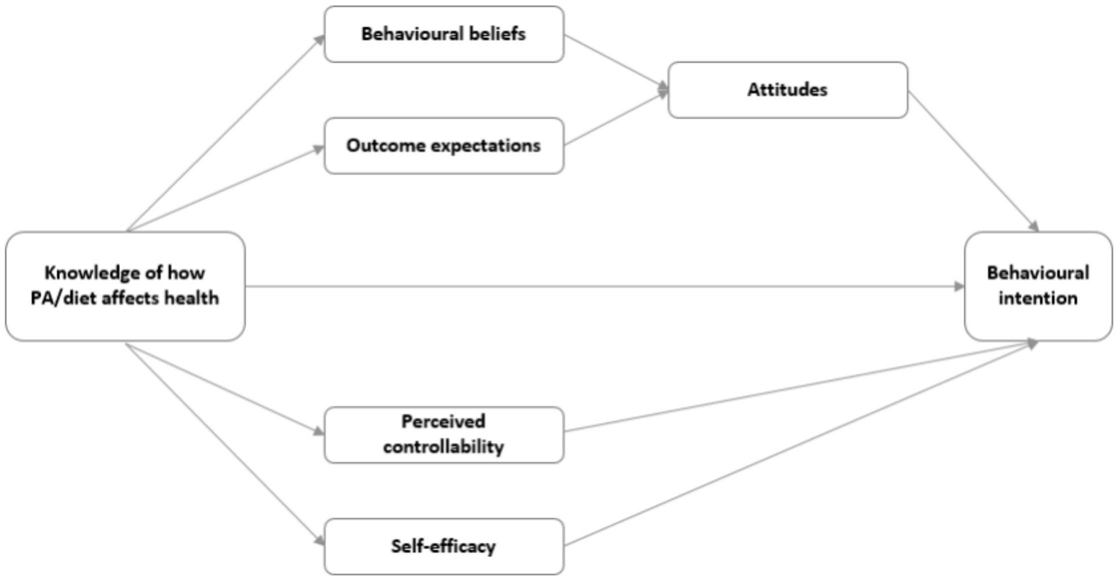


Figure 6.2 Process model for the effects of knowledge on behavioural intention, based on the TPB



In the final study, the mismatch framed resources were developed into a more interactive and comprehensive online intervention that was intended to promote behaviour change. While the resources that had been tested in Study 2 had led to increases in motivation and self-efficacy for behaviour change, in the online intervention techniques were added to promote self-regulatory skills (goal setting and self-monitoring, action and coping planning), with the aim of helping participants implement behaviour changes (Nurmi et al., 2016; Teixeira et al., 2015). The intervention was delivered in a self-directed manner involving a one-off introductory session, where the researcher showed the participant how to use the website and set goals, and gave them a pedometer. Then participants were free to read the website content in their own time and set goals that were meaningful to them; they were asked (and reminded by email for the first 6 weeks) to record their progress towards their goals each week. This format of intervention delivery was intended to be cost-effective should the intervention be rolled out further. A randomised controlled trial involving 59 participants was conducted to assess the effectiveness of the intervention (Study 3, Chapter 5). After 12 weeks, small but meaningful improvements in physical activity and diet were found; these tended to be greater than the changes seen in the control group, although not significantly so. Positive changes were also found in several health markers, suggesting the intervention could lead to behaviour changes sufficient to reduce people's risk of developing T2DM and CVD. The mechanisms through which the intervention influenced behaviour were also investigated. Small but meaningful increases in motivation, self-efficacy, self-regulation and habit strength were found. A qualitative evaluation of the intervention was also conducted exploring participants' perceptions of, and experiences with, the intervention. Generally the intervention had been positively received; participants valued the mismatch framed educational content and highlighted the particular importance of the self-regulatory techniques for helping them make behaviour changes.

6.2 Overall interpretation and future directions

The underlying idea behind this thesis was to see if using the concept of an evolutionary mismatch in a health promotion intervention could help people to make healthy behaviour changes. The findings of the research presented here give promising indication that framing health information in a behaviour change intervention from the perspective of an evolutionary mismatch can promote interest in the intervention and provide a meaningful rationale to improve motivation for behaviour change. An interesting next step would be to conduct a further RCT of the intervention with a larger sample and over a longer period (e.g. a year) to evaluate how well the intervention can sustain engagement and whether users maintain any healthy behaviours they adopt. Maintenance of healthy behaviours following changes prompted by interventions has been highlighted as a concern in the area of weight loss, with the majority of people who have successfully lost weight in non-surgical interventions regaining all the weight lost over the following three to five years (Greaves et al., 2017). The intervention did lead to increases of meaningful effect size in autonomous motivation, which sustained from 6 to 12 weeks over the trial; applying SDT, an increase in autonomous motivation should help people to maintain their new behaviours as they will be personally valued by the individual. However, autonomous motivation may wane over time, and this may perhaps be more likely if engagement with the intervention diminishes. The majority of participants felt that they would not continue to use the website or record their behaviour, instead feeling that they had formed new habits. A longer study would enable testing of how long people choose to continue engaging with the intervention and the different effects that different, self-selected 'doses' of the intervention have in terms of behaviour maintenance. For example, three months' engagement with the intervention may not be sufficient for people to form new habits and sustain their healthy behaviours at 12-month follow-up, but six months engagement might yield better results. These results may vary according to individual differences and the type of behaviour (Ory, Smith, Mier & Wernicke, 2010); for example, active commuting to work may be easier to keep up than a new sport that has to be fitted in to leisure time. As the formation of new habits requires the continued, regular repetition of the behaviour in consistent contexts (Lally & Gardner, 2013), new behaviours that can be linked to more stable aspects of an individual's life (such as the need to get to and from work each day) are more likely to become habitual. In relation to the present intervention, where participants are free to choose which behaviours they change, the potential for high levels of individual variability means that very large sample sizes would be needed to explore the moderating effects of context and type of behaviour on the relationship between length of engagement with the intervention and habit formation.

In a future study, different strategies could also be tried in the intervention to sustain engagement. Regularly updating website content has been associated with users making more return visits (Brouwer et al., 2011; Brouwer et al., 2009), the updates adding novel material that should promote interest (Silvia, 2005). During the interviews in Study 3, participants suggested that including more tips and narratives on activity and dietary changes to make would have been helpful, and some participants wanted a news page that would discuss new scientific health findings, in lay terms, and relate them to the mismatch concept. Adding this content could be done in a phased manner, which would help to ensure the website is updated with novel content and may also prevent users feeling overwhelmed by being given too much content all at once. The ability to record and monitor behaviour on a website is another predictor of re-visiting (Brouwer et al., 2009); the results of Study 3 support this, with participants reporting that they would log on to the website at least once a week if only to record their progress towards their goals. The goal recording area of the Evolife website was relatively simple, providing generic feedback messages based on whether or not participants had met their weekly goals. Although participants were prompted to gradually increase their goals over the course of the intervention, this was not monitored by the website. This was mainly because participants were free to set their own goals and so a generic algorithm would not have been capable of monitoring change in these goals. However, it should be possible for software to detect changes in step goals and so this function could be added to the website. Indeed, the website could be set to automatically set a user's goal, gradually increasing it from the previous week - some commercially available activity monitoring devices, such as the Activity app in the Apple Watch (Apple Inc., 2018), can be set to automatically increase fitness goals each week. Having novel targets to aim for may help to sustain interest (Silvia, 2005) and it would be necessary to revisit the website to check what goals had been set. However, many participants also reported that they liked having control over choosing their goals – this is likely to make their goals more meaningful and relevant, which in turn may make people more likely to strive to achieve them (Bovend'Eerdt, Botell & Wade, 2009). Allowing people to override automatically set goals may therefore be necessary.

A larger study of the intervention over a longer period might also better enable the process through which the intervention exerts its effects to be determined. The process analyses conducted in Studies 2 and 3 found only partial support for the hypothesised processes of change, potentially due to the relatively small sample sizes but also the changes made by the comparator groups. A no-intervention condition might provide a better comparison; although the control condition in Study 3 aimed to mimic usual advice given to NHS patients after their Health Check, it became apparent that many of the participants had completed a Health Check (and been told they were at high risk of disease) yet none had subsequently received any advice or support to change their behaviour. The type of comparator condition used in RCTs can have substantial impact on effect sizes (Cugelman, Thelwall & Dawes, 2011; Karlsson & Bergmark, 2015), and more active comparators (e.g. that involve more contact with a researcher or resource) are more likely to lead to improvement in the comparator group (Cugelman et al., 2011; Waters et al., 2012). Given that only partial support was found for the hypothesised process models, it is not possible to draw clear conclusions on the theories applied in this work (SDT and TPB). However, that is not to say that applying these theories in the development of the intervention was unbeneficial as they helped to provide a structure, identify evidence-based cognitive determinants to target and enable standardised measures to be used. The qualitative data did suggest that people found the mismatch concept provided a meaningful rationale and this seemed to boost their reported motivation for behaviour change (as predicted based on SDT). The qualitative data also suggested that knowledge (of *how* physical activity and diet impact health, and how to change behaviour) could influence people's attitudes and self-efficacy (as predicted based on TPB). However, the quantitative data may indicate that these perceived effects were either not to the extent people believed, or that the degree of change in these mediators was not sufficient to bring about measurable change in behaviour.

To conduct a larger study, however, needs careful consideration. The intervention led to only modest improvements in behaviour, health markers and cognitions; the potential cost savings this could generate need to be considered against the high costs of conducting trials. On the other hand, even small effects at an individual level can lead to large improvements in health at a population level (Fitzgibbon et al., 2007). Brief advice and brief interventions are increasing in popularity as, although they tend to lead to only modest individual changes they can be delivered at a large scale to reach many people and thus have shown good cost-effectiveness for advice and interventions on physical activity (Anokye, Lord & Fox-Rushby, 2013) and weight loss (Beeken et al., 2016).

It is important to note that all the participants in the three studies included in this thesis were living in Britain, the majority being British citizens. Evolutionary theory is taught in British schools and accepted by the majority of the population. However, this is not the case throughout the world – many countries do not teach or discuss evolutionary theory, often because it is seen to conflict with ideas of the countries' dominant religions. This limits the external validity of the Evolife intervention trial as the intervention is unlikely to be accepted in countries or societies where evolutionary theory is not acknowledged or believed. The Evolife intervention was also targeted at adults aged 35 to 74 years, who seemed to like the combination of text and graphic information, and use of a stand-alone pedometer in conjunction with a website. A younger audience might, however, prefer less text and more integrated technology (e.g. an activity monitor that automatically synchronises data with a mobile app). Younger generations have grown up with information being delivered, often in graphic or audio format, via digital devices that can synchronise all their data; the Evolife intervention therefore might feel 'old-fashioned' to a younger population, which could make it less acceptable. Future research could investigate how best to adapt the Evolife intervention for audiences of different cultures and ages. For example, for younger audiences, a mobile app-based intervention that delivers small amounts of information at a time and can be integrated with wrist-worn activity monitors, may be more appropriate. In cultures where evolutionary theory is not accepted it would likely be necessary to remove all evolutionary mismatch content, as was done in the non-evolutionary booklet used in Study 2.

Throughout this research, the urgent need for cost-effective interventions was borne in mind. The Evolife intervention presents a reasonably low-cost format that could be delivered, for example, by primary care practitioners to people identified in their NHS Health Check as being at high risk of T2DM and CVD. While the intervention could be delivered entirely remotely (e.g. individuals search for and register on the website and have a pedometer posted out to them), the set-up session might be important for promoting engagement with the intervention. Some participants in Study 3 had questions about using the website, particularly goal setting, which it was helpful to resolve at the start of the intervention. Furthermore, several participants commented that the researcher's positivity had helped motivate them to engage with intervention. This was not formally evaluated, and the comments may have been due to participants wanting to please the researcher (though the comments were not sought); however the consultation style of health practitioners is known to impact on the effectiveness of behaviour change interventions delivered in primary care (Butler et al., 2013) and it seems likely that a positive meeting with a practitioner could increase the likelihood of at least visiting the website for the first time. Although face-to-face meetings with health practitioners add to the cost of an intervention, the human interaction involved may be an important ingredient for an effective intervention (Kelley, Kraft-Todd, Schapira, Kossowsky & Riess, 2014). For example, practitioners can offer empathy and imbue their communications with added meaning, through tone and body language, in a way that technology cannot (Rodham, 2018).

A recent workshop on the use of digital technology in healthcare highlighted that the early predictions that digitalisation would revolutionise healthcare, simultaneously improving patient experience and reducing costs, have as yet been unfulfilled (Michie, Yardley, West, Patrick & Greaves, 2017). One of the many challenges to the digitalisation of healthcare, identified in the workshop, is finding effective ways to promote engagement with digital interventions (Michie et al., 2017); combining brief introductory consultations with a healthcare practitioner and an otherwise self-directed online intervention may present an effective and cost-effective option if the human contact can promote initial engagement with the online content. To minimise costs the consultation could be with trained volunteers or non-clinical members of healthcare staff. A study by Butler and colleagues (2013) assessed the effects of training primary care practitioners to deliver brief behaviour change counselling (relating to physical activity, diet, smoking and alcohol) in their consultations. The counselling style was informed by the principles of motivational interviewing, a patient-centred technique that aims to guide an individual to decide for themselves if and how to change their behaviour (Miller & Rose, 2009; Rollnick et al., 2005). Following a one-off consultation with the trained practitioners (compared with a control group of patients who consulted practitioners who had not been trained in the behavioural counselling), patients reported being engaged with the topics covered, having a greater intention to change and, at three months, having made an attempt to change (Butler et al., 2013). However, actual behaviour and biometric health markers were not found to have improved at 3- or 12-months follow-up. This was perhaps due to the lack of support following the consultation: a need that could be fulfilled by a digital, self-directed resource, such as a website.

On a related note, the periodic interaction with the researcher that all participants in Study 3 had for assessment visits may also have helped sustain behaviour change over the course of the study. Future research could compare the effects of different schedules of contact with intervention providers. For example, brief appointments or telephone calls with the intervention provider could be held at regular intervals (e.g. every three months) to ask how the individual is managing with their new behaviours and provide encouragement. Different intervals between appointments could be compared to see the minimum 'dose' sufficient to maintain behaviour changes. While it has been shown that increased total contact time with intervention providers tends to lead to greater adherence to health behaviour changes (Middleton, Anton & Perri, 2013), the regularity of contact has not been investigated in terms of effectiveness or cost-effectiveness.

Social support has been found to be the strongest predictor of effectiveness in physical activity and dietary interventions (Greaves et al., 2011) and, ideally, individuals would enlist support for behaviour change from friends and family so that, with time, no further contact with intervention providers would be needed. However, in the present study and other behaviour change interventions (e.g. Gillison et al., 2015), encouraging people to seek support from their social circles has proven to be difficult. Little has been done to identify how best to help people foster support from their friends, colleagues and family – this could be an interesting area for future research. Finding ways of prompting people to enlist social support through online interventions may be a particularly fruitful line of enquiry since no direct human contact is provided by these interventions. Online health interventions have recently been criticised for promoting social isolation as they encourage a focus on the self and dependency on technology rather than building supportive relationships with other people (Rodham, 2018). However, this does not imply that digital technology should not be used for health promotion; technology offers many benefits that humans cannot, such as providing constant monitoring of activity, and providing feedback or information at any time and place to suit the individual. Instead, more research is needed to find effective ways of integrating human and technological support in interventions.

In Study 2 the non-mismatch framed resources brought about improvements in cognitive determinants of behaviour change that were mostly on a par with those of the mismatch framed resources. The non-mismatch framed resources provided a greater depth of physiological information than is included in standard educational health promotion resources, such as the One You website provided by the NHS and Public Health England (Public Health England, 2018). The results of Study 2 suggest that the depth of information provided in the resources (specifically, explaining the mechanisms linking our lifestyle to health outcomes) was understandable, even to a sample of varied educational attainment, and that it can help improve determinants of behaviour change. This perhaps implies that health promotion resources and interventions should not shy away from providing physiological information that helps people understand how their bodies work. The main arguments against providing complex or in-depth information in health promotion have been that it is unlikely to be understood or remembered (Piggin, 2012; Piggin & Lee, 2011) and it may appear overwhelming at first glance, so people will be unlikely to attend to it (Silvia, 2006). However, these arguments seem to relate more to the way in which the information is provided rather than the depth of information per se. The studies depicted in this thesis have shown that complex information can be conveyed in attractive, understandable and memorable formats. The challenge, however, will be to prompt initial engagement with more complex information among the general public who may not be interested or motivated to learn. The participants in the three studies of this thesis all volunteered to take part and thus are likely to have had a higher level of motivation to engage with the resources than could be assumed to be present in the general public. As mentioned above, this might be where face-to-face consultations with trained intervention providers or health practitioners could play a key role, developing a rapport with people in order to build trust and help motivate them to engage, and then introducing them to informational resources that can be viewed in their own time.

Before taking part in Study 3, very few of the participants in the control group had heard of or visited any of the three NHS websites that they were shown (NHS Choices, One You and Change 4 Life); yet their participation implies that they were all interested in improving their health. These websites contain a lot of information to help people make healthy lifestyle choices and yet they do not seem to be exploited to their full potential. Perhaps more extensive or targeted advertising of these resources is needed – for example, health care practitioners could actively promote the websites to people after they have completed their Health Check. However, based on the findings from this thesis, some adaptations to these existing NHS websites might help to boost their potential to support healthy lifestyles. Firstly, none of the websites explain the mechanisms by which our lifestyles affect our health. For example, the pages on exercise included on the NHS Choices site cover: the government physical activity guidelines for different age groups; a list of the health benefits of exercise; explanations of what counts as moderate, vigorous and strengthening activities; and gives tips for increasing one's activity. Although it is stated under 'Health benefits' that people who are regularly active have "up to a 50% lower risk of type 2 diabetes", no explanation of why physical activity lowers a person's risk is given. This mechanistic physiological information was contained in both the mismatch framed and non-mismatch framed resources in Study 2 and both sets of resources led to improvements in cognitive determinants of change. Although Study 2 did not compare the resources with the NHS websites (i.e. there was not a third group of participants directed to these sites), it is possible that explaining the physiological mechanisms helped to provide novelty (thus increasing interest) and a strong rationale for adopting healthy behaviours, which in turn promoted autonomous motivation. Future studies could test this hypothesis and, if supported, the existing NHS resources could be extended with more explanations of the physiological mechanisms linking lifestyle and health.

A second adaptation to the NHS websites, to improve their ability to effect behaviour change, would be to incorporate features that sustain engagement, both on a single visit to the sites and to encourage return visits. In Study 3, participants in the control condition tended to report visiting the NHS websites once or twice soon after the set-up session but no further engagement. Although not formally assessed in the study, several of the control participants commented to the researcher (during subsequent assessment visits) that they found the NHS Choices website hard to navigate as many of the pages contained hyperlinks that would take them to different sections, making it easy to lose track of what they had seen. There is very little interactive content on any of the websites, although the One You website does contain a 'How are you?' quiz that gives users a quick assessment of their lifestyle and all of the websites direct users to downloadable apps that can help them monitor their activity and diet. Although, in the set-up sessions, the researcher specifically showed participants where these apps could be found on the websites, only five people downloaded an app and none continued to use them to the end of the study. It may have been that people in the control group felt less motivated to engage with resources that they perceive to be inferior (since they are not the main study condition); however, it is likely that the lack of engagement also reflects shortcomings in the websites' and apps' design. While the Evolife website could also be improved in terms of maintaining engagement, its simple layout was reported to be attractive and is markedly different from the NHS sites, which tend to have less 'white space' (i.e. portions of the page with no text or graphic content). The first impression that a person makes of a website (or app) has been shown to be a key determinant of whether or not they will make a return visit, and attractiveness and ease of use are factors with a strong influence on these impressions (Crutzen, de Kruif & de Vries, 2012). Perhaps another advantage of the Evolife website was that it contained both information and behavioural monitoring features (for physical activity and diet), whereas the NHS resources separate these features – the websites contain information and different apps are required for monitoring different behaviours. Developing and testing the NHS resources with target users, as has been done throughout the current work, could help to make them more attractive, easier to use and increase the likelihood of them meeting the needs of the public.

A particular benefit of applying the evolutionary mismatch concept to a health promotion intervention is that it provides insight into multiple aspects of our lifestyles that affect health. In the present work, the mismatch concept was applied to physical activity and diet, and a growing body of evidence shows that combined interventions targeting both these factors are more effective for weight loss and health outcomes than interventions targeting only one lifestyle factor (Greaves et al., 2011; Johns et al., 2014). The mismatch concept can also be applied to the two other main lifestyle factors associated with preventable disease and premature mortality: tobacco smoking and alcohol consumption (Danaei et al., 2009; Mokdad et al., 2004). Both tobacco and alcohol were extremely rare before the agricultural revolution (Konner & Eaton, 2010) and so they represent relatively recent stimuli that the human body has not evolved to consume, at least not in the quantities taken in today's society. A brief section on alcohol, from a mismatch perspective, was added to the intervention website in Study 3 as a result of feedback received in the first two studies that alcohol consumption was an issue on which participants wanted information and support. This could be expanded in future work to take a more in-depth look, from an evolutionary perspective, at the way the human body processes (or fails to) cigarette smoke and alcohol.

Obesity has been identified as a complex problem that will require a multifaceted system of intervention in order to be overcome (Butland et al., 2007). While the individual-level approach that has been the focus of the current thesis can help in tackling obesity and associated chronic disorders, intervention at the population level is needed too and may have greater effect. The evolutionary mismatch could be used as an educational tool to help policy makers, town planners and producers consider the possible health implications of policies, landscapes and technology. For example, by educating town planners about the mismatch concept they may place a higher focus on availability of pedestrian and cycle routes when considering new developments, rather than focusing on how many people can be housed in a certain area or which is the cheapest and most direct route for a new road to go. Similarly, producers and technology developers could be taught to apply the mismatch concept and consider how a new design is likely to affect our behaviour – will it encourage sedentary behaviour? Arguably we have reached the point where these health considerations need to come above profits and our drive to continually develop technology. This is not to say that we should stop developing technology or regress to living without automation; but humans do perhaps need to start asking, as we continue to develop technology and build environments for our expanding population, where advancements could lead and what they will do to our health. Rather than being a restrictive approach, this stance may foster creativity and innovation to develop technologies and infrastructure that positively impact health as well as enabling the intellectual advancement that humans seek. Educating the planners, producers and policy makers, whose decisions affect many people, may thus be an effective 'upstream' intervention with wide-reaching impact (Brownson, Seiler & Eyler, 2010). The evolutionary mismatch concept provides a framework that incorporates many of the different factors that affect physical and mental health (such as physical activity, availability of energy dense foods, access to green space, pollution etc.) in a cohesive manner. This may be a more helpful educational tool for policy makers, planners and producers than simply providing a list of all the different factors they need to consider as it links the factors together, encouraging cognitive elaboration and retention in memory (Petty & Cacioppo, 1986) as well as providing a comprehensive rationale for considering these factors.

6.3 Conclusion

This thesis presents an exploration of using the concept of an evolutionary mismatch in a health behaviour change intervention. The findings suggest that the mismatch concept may help to strengthen the rationale for increasing activity and consuming a healthier diet, and also help to generate initial interest in an intervention. The intervention evaluated in the present work led to modest improvements in the behaviour and health of participants (overweight adults), as well as increasing their motivation and self-efficacy to make healthy changes. This work did not find framing intervention materials from the perspective of an evolutionary mismatch to provide significant advantage over providing in-depth physiological health information or directing people to existing NHS health information resources; thus it cannot be ruled out that the mismatch concept was not an ‘active ingredient’ in the intervention. However, it does not have a negative impact and, at least for some participants, the mismatch concept seemed to help make health messages more meaningful.

Ultimately physical inactivity, poor diet, obesity and the associated chronic diseases in high income societies are complex, related problems and tackling them will require a multi-pronged approach (Butland et al., 2007). Individual-level interventions, such as the one developed and tested in this thesis, can form part of the solution but without environmental and cultural change as well, individuals will always be facing an uphill struggle to work against a society that minimises activity and provides multiple cues to consume energy-dense foods. The evolutionary mismatch concept provides insight into these and other issues impacting on public health and might prove useful as a framework to inform population-level interventions that shape policy and the environment. As well as helping to inform future work on individual-level interventions, the research presented in this thesis can provide insight into how to educate policy makers and producers on the mismatch concept and how it applies to their work. There is much still to be done to help people lead healthier lives; the work presented here suggests some exciting paths for future research towards this goal.

References

Abraham, C. (2012a). Developing Evidence-based Content for Health Promotion Materials. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.

Abraham, C. (2012b). Mapping Change Mechanisms onto Behaviour Change Techniques: A Systematic Approach to Promoting Behaviour Change Through Text. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.

Abraham, C. (2014). Mapping modifiable mechanisms in health promotion research: a commentary on Sniehotta, Presseau, and Araújo-Soares. *Health Psychology Review*, 1-5.

Abraham, C. & Kools, M. (2012). Introduction: Steps Towards Writing Effective Educational Text. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.

Abraham, C. & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychology, 27*(3), 379-387.

Ahima, R. S., Prabakaran, D., Mantzoros, C., Qu, D., Lowell, B., Maratos-Flier, E. & Flier, J. S. (1996). Role of leptin in the neuroendocrine response to fasting. *Nature, 382*(6588), 250-252.

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett, D. R., Tudor-Locke, C., . . . Leon, A. S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine & Science in Sports & Exercise, 43*(8), 1575-1581.

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control* (pp. 11-39): Springer Berlin Heidelberg.

Ajzen, I. (2002). Constructing a TPB questionnaire: Conceptual and methodological considerations: University of Massachusetts Amherst

Ajzen, I. (2006). Constructing a TPB Questionnaire: Conceptual and Methodological Considerations. www.uni-bielefeld.de/ikg/zick/ajzen%20construction%20a%20tpb%20questionnaire.pdf

Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. *Psychology & Health, 26*(9), 1113-1127.

Ajzen, I., Joyce, N., Sheikh, S. & Cote, N. G. (2011). Knowledge and the Prediction of Behavior: The Role of Information Accuracy in the Theory of Planned Behavior. *Basic and Applied Social Psychology, 33*(2), 101-117.

Albarracín, D., Durantini, M. R., Earl, A., Gunnoe, J. B. & Leeper, J. (2008). Beyond the Most Willing Audiences: A Meta-Intervention to Increase Exposure to HIV-Prevention Programs by Vulnerable Populations. *Health Psychology, 27*(5), 638-644.

Amireault, S., Godin, G. & Vézina-Im, L.-A. (2012). Determinants of physical activity maintenance: a systematic review and meta-analyses. *Health Psychology Review, 7*(1), 55-91.

Ammann, R., Vandelanotte, C., de Vries, H. & Mummery, W. K. (2013). Can a Website-Delivered Computer-Tailored Physical Activity Intervention Be Acceptable, Usable, and Effective for Older People? *Health Education & Behavior, 40*(2), 160-170.

Ammerman, A. S., Lindquist, C. H., Lohr, K. N. & Hersey, J. (2002). The Efficacy of Behavioral Interventions to Modify Dietary Fat and Fruit and Vegetable Intake: A Review of the Evidence. *Preventive Medicine, 35*(1), 25-41.

Anderson, E., Winett, R. & Wojcik, J. (2007). Self-regulation, self-efficacy, outcome expectations, and social support: Social cognitive theory and nutrition behavior. *Annals of Behavioral Medicine, 34*(3), 304-312.

Anderson, E., Winett, R., Wojcik, J., Winett, S. & Bowden, T. (2001). A computerized social cognitive intervention for nutrition behavior: Direct and mediated effects on fat, fiber, fruits, and vegetables, self-efficacy, and outcome expectations among food shoppers. *Annals of Behavioral Medicine, 23*(2), 88-100.

Anokye, N. K., Lord, J. & Fox-Rushby, J. (2013). Is brief advice in primary care a cost-effective way to promote physical activity? *British Journal of Sports Medicine*.

Appel, M. & Richter, T. (2007). Persuasive Effects of Fictional Narratives Increase Over Time. *Media Psychology, 10*(1), 113-134.

Apple Inc. (2018). Watch. Retrieved July, 2018, from https://www.apple.com/uk/watch/

Archer, E. & Blair, S. N. (2011). Physical Activity and the Prevention of Cardiovascular Disease: From Evolution to Epidemiology. *Progress in Cardiovascular Diseases, 53*(6), 387-396.

Arentson-Lantz, E., Clairmont, S., Paddon-Jones, D., Tremblay, A. & Elango, R. (2015). Protein: A nutrient in focus. *Applied Physiology, Nutrition, and Metabolism*, 1-7.

Arthaud, J. B. (1970). Cause of death in 339 Alaskan natives as determined by autopsy. *Archives of Pathology, 90*(5), 433-438.

Atak, N., Gurkan, T. & Kose, K. (2008). The effect of education on knowledge, self management behaviours and self efficacy of patients with type 2 diabetes. *The Australian Journal of Advanced Nursing, 26*(2), 66-74.

Avenell, A., Broom, I., Brown, T., Poobalan, A. & Aucott, L. (2004). Systematic review of the long-term effects and economic consequences of treatments for obesity and implications for health improvement. *Health Technology Assessment, 8*(21), 194.

Ballantine, P. W. & Stephenson, R. J. (2011). Help me, I'm fat! Social support in online weight loss networks. *Journal of Consumer Behaviour, 10*(6), 332-337.

Bandura, A. (1997). *Self-efficacy: the exercise of control*. New York: W. H. Freeman.

Bandura, A. (2004). Health Promotion by Social Cognitive Means. *Health Education & Behavior, 31*(2), 143-164.

Banks, W. A. (2001). Leptin transport across the blood-brain barrier: implications for the cause and treatment of obesity. *Current Pharmaceutical Design, 7*(2), 125-133.

Barrera , M., Strycker, L. A., MacKinnon, D. P. & Toobert, D. J. (2008). Social-ecological resources as mediators of two-year diet and physical activity outcomes in type 2 diabetes patients. *Health Psychology, 27*(2, Suppl), S118-S125.

Bartholomew, L. K., Parcel, G. S. & Kok, G. (1998). Intervention mapping: a process for developing theory- and evidence-based health education programs. *Health Education & Behavior, 25*(5), 545-564.

Batterham, M., Tapsell, L. C. & Charlton, K. E. (2016). Baseline characteristics associated with different BMI trajectories in weight loss trials: a case for better targeting of interventions. *European Journal of Clinical Nutrition, 70*(2), 207-211.

Baumeister, R. F., Gailliot, M., DeWall, C. N. & Oaten, M. (2006). Self-Regulation and Personality: How Interventions Increase Regulatory Success, and How Depletion Moderates the Effects of Traits on Behavior. *Journal of Personality, 74*(6), 1773-1802.

Beeken, R. J., Leurent, B., Vickerstaff, V., Wilson, R., Croker, H., Morris, S., . . . Wardle, J. (2016). A brief intervention for weight control based on habit-formation theory delivered through primary care: results from a randomised controlled trial. *International Journal Of Obesity, 41*, 246.

Bélanger-Gravel, A., Godin, G. & Amireault, S. (2013). A meta-analytic review of the effect of implementation intentions on physical activity. *Health Psychology Review, 7*(1), 23-54.

Bellg, A. J. (2003). Maintenance of Health Behavior Change in Preventive Cardiology: Internalization and Self-Regulation of New Behaviors. *Behavior Modification, 27*(1), 103-131.

Berkman, N. D., Davis, T. C. & McCormack, L. (2010). Health Literacy: What Is It? *Journal of Health Communication, 15*(S2), 9-19.

Berntsen, S., Hageberg, R., Aandstad, A., Mowinckel, P., Anderssen, S. A., Carlsen, K. H. & Andersen, L. B. (2010). Validity of physical activity monitors in adults participating in free-living activities. *British Journal of Sports Medicine, 44*(9), 657.

Bhatnagar, P., Wickramasinghe, K., Wilkins, E. & Townsend, N. (2016). Trends in the epidemiology of cardiovascular disease in the UK. *Heart, 102*(24), 1945.

Blair, S. (2015, April 24, 2015). Physical Inactivity and Obesity is Not a Myth: Dr. Steven Blair Comments on the BJSM Editorial. Retrieved April 26, 2015, from https://gebn.org/news/home/item/26-physical-activity-is-not-a-myth?utm_content=buffer7ae00&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Blair, S. N., LaMonte, M. J. & Nichaman, M. Z. (2004). The evolution of physical activity recommendations: how much is enough? *The American Journal of Clinical Nutrition, 79*(5), 913S-920S.

Block, L. G., Grier, S. A., Childers, T. L., Davis, B., Ebert, J. E. J., Kumanyika, S., . . . van Ginkel Bieshaar, M. N. G. (2011). From Nutrients to Nurturance: A Conceptual Introduction to Food Well-Being. *Journal of Public Policy & Marketing, 30*(1), 5-13.

Boers, I., Muskiet, F. A. J., Berkelaar, E., Schut, E., Penders, R., Hoenderdos, K., . . . Jong, M. C. (2014). Favourable effects of consuming a Palaeolithic-type diet on characteristics of the metabolic syndrome: a randomised controlled pilot-study. *Lipids in Health and Disease, 13*(160).

Bol, N., van Weert, J. C. M., Loos, E. F., Romano Bergstrom, J. C., Bolle, S. & Smets, E. M. A. (2016). How Are Online Health Messages Processed? Using Eye Tracking to Predict Recall of Information in Younger and Older Adults. *Journal of Health Communication, 21*(4), 387-396.

Booth, F. W., Chakravarthy, M. V., Gordon, S. E. & Spangenburg, E. E. (2002). Waging war on physical inactivity: using modern molecular ammunition against an ancient enemy. *Journal of Applied Physiology, 93*(1), 3-30.

Booth, F. W., Chakravarthy, M. V. & Spangenburg, E. E. (2002). Exercise and gene expression: physiological regulation of the human genome through physical activity. *The Journal of Physiology, 543*(2), 399-411.

Booth, F. W., Laye, M. J., Lees, S. J., Rector, R. S. & Thyfault, J. P. (2008). Reduced physical activity and risk of chronic disease: the biology behind the consequences. *European Journal of Applied Physiology, 102*(4), 381-390.

Botchwey, N. D., Falkenstein, R., Levin, J., Fisher, T. & Trowbridge, M. (2015). The Built Environment and Actual Causes of Death : Promoting an Ecological Approach to Planning and Public Health. *Journal of Planning Literature, 30*(3), 261-281.

Boutron, I., Moher, D., Altman, D. G., Schulz, K. F. & Ravaud, P. (2008). Extending the CONSORT Statement to Randomized Trials of Nonpharmacologic Treatment: Explanation and Elaboration. *Annals of Internal Medicine, 148*(4), 295-309.

Bovend'Eerdt, T. J. H., Botell, R. E. & Wade, D. T. (2009). Writing SMART rehabilitation goals and achieving goal attainment scaling: a practical guide. *Clinical Rehabilitation, 23*(4), 352-361.

BPLTT Collaboration. (2003). Effects of different blood-pressure-lowering regimens on major cardiovascular events: results of prospectively-designed overviews of randomised trials. *The Lancet, 362*(9395), 1527-1535.

Bramble, D. M. & Lieberman, D. E. (2004). Endurance running and the evolution of Homo. *Nature, 432*(7015), 345-352.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Braun, V. & Clarke, V. (2013). *Successful Qualitative Research: A Practical Guide for Beginners*. London, UK: SAGE Publications Ltd.

Breslin, P. A. (2013). An evolutionary perspective on food and human taste. *Current Biology, 23*(9), R409-418.
Bridges, S., Doyle, M., Fuller, E., Knott, C., Mindell, J., Moody, A., . . . Whalley, R. (2013). Health Survey for England - 2012. In R. Craig & J. Mindell (Eds.). The Health and Social Care Information Centre.
British Nutrition Foundation. (2015). Nutrient requirements. Retrieved 19th February, 2015, from https://www.nutrition.org.uk/nutritionscience/nutrients-food-and-ingredients/nutrient-requirements.html
Brooks, R. (1996). EuroQol: the current state of play. *Health Policy, 37*(1), 53-72.
Brouwer, W., Kroeze, W., Crutzen, R., de Nooijer, J., de Vries, N. K., Brug, J. & Oenema, A. (2011). Which Intervention Characteristics are Related to More Exposure to Internet-Delivered Healthy Lifestyle Promotion Interventions? A Systematic Review. *Journal of Medical Internet Research, 13*(1), e2.
Brouwer, W., Oenema, A., Crutzen, R., de Nooijer, J., de Vries, N. K. & Brug, J. (2009). What makes people decide to visit and use an internet-delivered behavior-change intervention?: A qualitative study among adults. *Health Education, 109*(6), 460-473.
Brownson, R. C., Seiler, R. & Eyler, A. A. (2010). Measuring the Impact of Public Health Policy. *Preventing Chronic Disease, 7*(4), A77.
Brug, H. & Oenema, A. (2012). Computer-tailoring of Health Promotion Messages. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: Sage Publications Ltd.
Burke, L. E., Wang, J. & Sevick, M. A. (2011). Self-Monitoring in Weight Loss: A Systematic Review of the Literature. *Journal of the American Dietetic Association, 111*(1), 92-102.
Butland, B., Jebb, S., Kopelman, P., McPherson, K., Thomas, S., Mardell, J. & Parry, V. (2007). Tackling Obesities: Future Choices - Project Report (2nd ed.). London: Department of Innovation Universities and Skills.
Butler, C. C., Simpson, S. A., Hood, K., Cohen, D., Pickles, T., Spanou, C., . . . Rollnick, S. (2013). Training practitioners to deliver opportunistic multiple behaviour change counselling in primary care: a cluster randomised trial. *British Medical Journal, 346*.
Byrne, M. & Curtis, R. (2000). Designing health communication: Testing the explanations for the impact of communication medium on effectiveness. *British Journal of Health Psychology, 5*(2), 189-199.
Byrne, S. & Niederdeppe, J. (2011). Unintended consequences of obesity prevention messages. In J. Crawley (Ed.), *The Oxford Handbook of the Social Science of Obesity* (pp. 752 - 770). New York: Oxford University Press.
Cappella, J. N. (2006). Integrating Message Effects and Behavior Change Theories: Organizing Comments and Unanswered Questions. *Journal of Communication, 56*, S265-S279.
Carmody, R. N., Weintraub, G. S. & Wrangham, R. W. (2011). Energetic consequences of thermal and nonthermal food processing. *Proceedings of the National Academy of Sciences, 108*(48), 19199-19203.
Carmody, R. N. & Wrangham, R. W. (2009). The energetic significance of cooking. *Journal of Human Evolution, 57*(4), 379-391.
Cavalli-Sforza, L. L. (1981). Human evolution and nutrition. In D. N. Walcher & N. Kretchmer (Eds.), *Food, nutrition and evolution: food as an environmental factor in the genesis of human variability* (pp. 1-7). New York: Masson.
Cavill, N. & Bauman, A. (2004). Changing the way people think about health-enhancing physical activity: do mass media campaigns have a role? *Journal of Sports Sciences, 22*(8), 771-790.
Cebr. (2014). The economic cost of cardiovascular disease from 2014-2020 in 6 European economies. London: Centre for Economics and Business Research.

Chaiken, S. & Eagly, A. H. (1976). Communication modality as a determinant of message persuasiveness and message comprehensibility. *Journal of Personality and Social Psychology, 34*(4), 605-614.
Chakravarthy, M. V. & Booth, F. W. (2004). Eating, exercise, and "thrifty" genotypes: connecting the dots toward an evolutionary understanding of modern chronic diseases. *Journal of Applied Physiology, 96*(1), 3-10.
Chatzisarantis, N. & Hagger, M. (2009). Effects of an intervention based on self-determination theory on self-reported leisure-time physical activity participation. *Psychology and Health, 24*(1), 29-48.
Chatzisarantis, N. L. D., Hagger, M. S. & Smith, B. (2007). Influences of perceived autonomy support on physical activity within the theory of planned behavior. *European Journal of Social Psychology, 37*(5), 934-954.
Chief Medical Officer. (2011). *Physical activity guidelines: adults (19-64 years)*. London, UK: The Crown.
Cohen, J. (2001). Defining Identification: A Theoretical Look at the Identification of Audiences With Media Characters. *Mass Communication and Society, 4*(3), 245-264.
Conner, M. & Norman, P. (2005). *Predicting health behaviour: research and practice with social cognition models* (2nd ed.). Maidenhead: Open University Press.
Conner, M. & Sparks, P. (2005). Theory of Planned Behaviour and Health Behaviour. In M. Conner & P. Norman (Eds.), *Predicting health behaviour: research and practice with social cognition models* (2nd ed., pp. 170 - 222). Maidenhead, UK: OUP.
Cordain, L. (2002). *The paleo diet: lose weight and get healthy by eating the food you were designed to eat*. Boston, US: Houghton Mifflin Harcourt.
Cordain, L. (2014a). Beans and legumes: are they Paleo? Retrieved from http://thepaleodiet.com/beans-and-legumes-are-they-paleo/
Cordain, L. (2014b). Dairy: Milking it for all it's worth. Retrieved from http://thepaleodiet.com/dairy-milking-worth/
Cordain, L., Eaton, S. B., Sebastian, A., Mann, N., Lindeberg, S., Watkins, B. A., . . . Brand-Miller, J. (2005). Origins and evolution of the Western diet: health implications for the 21st century. *The American Journal of Clinical Nutrition, 81*(2), 341-354.
Cordain, L., Gotshall, R. W., Eaton, S. B. & Eaton, S. B. (1998). Physical activity, energy expenditure and fitness: an evolutionary perspective. *International Journal of Sports Medicine, 19*(5), 328-335.
Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., . . . Oja, P. (2003). International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381-1395.
Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. & Petticrew, M. (2006). Developing and evaluating complex interventions: new guidance: Medical Research Council.
Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ, 337*.
Crano, W. D. & Prislin, R. (2006). Attitudes and Persuasion. *Annual Review of Psychology, 57*(1), 345-374.
Crawford, M. A., Bloom, M., Broadhurst, C. L., Schmidt, W. F., Cunnane, S. C., Galli, C., . . . Parkington, J. (1999). Evidence for the unique function of docosahexaenoic acid during the evolution of the modern hominid brain. *Lipids, 34*(1), S39-S47.
Crutzen, R., de Kruif, L. & de Vries, N. K. (2012). You never get a second chance to make a first impression: The effect of visual complexity on intention to use websites. *Interaction Studies, 13*(3), 469-477.
Crutzen, R. & Ruiter, R. (2015). Interest in behaviour change interventions: A conceptual model. *The European Health Psychologist, 17*(1), 6-11.

Crutzen, R., Ruiter, R. A. C. & de Vries, N. K. (2014). Can interest and enjoyment help to increase use of Internet-delivered interventions? *Psychology & Health, 29*(11), 1227-1244.
Cueva, M., Dignan, M., Lanier, A. & Kuhnley, R. (2014). Qualitative Evaluation of a Colorectal Cancer Education CD-ROM for Community Health Aides/Practitioners in Alaska. *Journal of Cancer Education, 29*(4), 613-618.
Cugelman, B., Thelwall, M. & Dawes, P. (2011). Online Interventions for Social Marketing Health Behavior Change Campaigns: A Meta-Analysis of Psychological Architectures and Adherence Factors. *J Med Internet Res, 13*(1), e17.
Cummings, D. E. & Overduin, J. (2007). Gastrointestinal regulation of food intake. *The Journal of Clinical Investigation, 117*(1), 13-23.
Danaei, G., Ding, E. L., Mozaffarian, D., Taylor, B., Rehm, J., Murray, C. J. L. & Ezzati, M. (2009). The Preventable Causes of Death in the United States: Comparative Risk Assessment of Dietary, Lifestyle, and Metabolic Risk Factors. *PLoS Medicine, 6*(4).
Darker, C. D., French, D. P., Eves, F. F. & Sniehotta, F. F. (2009). An intervention to promote walking amongst the general population based on an 'extended' theory of planned behaviour: A waiting list randomised controlled trial. *Psychology & Health, 25*(1), 71-88.
Davey, T. M., Allotey, P. & Reidpath, D. D. (2013). Is obesity an ineluctable consequence of development? A case study of Malaysia. *Public Health, 127*(12), 1057-1062.
Davies, C. A., Spence, J. C., Vandelanotte, C., Caperchione, C. M. & Mummery, W. K. (2012). Meta-analysis of internet-delivered interventions to increase physical activity levels. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 1-13.
Davis, R., Campbell, R., Hildon, Z., Hobbs, L. & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychology Review, 9*(3), 323-344.
Deaner, R. O. & Winegard, B. M. (2013). Throwing Out the Mismatch Baby with the Paleo-Bathwater. *Evolutionary Psychology, 11*(1), 263-270.
Deci, E. L., Eghrari, H., Patrick, B. C. & Leone, D. (1994). Facilitating internalization: The selfdetermination theory perspective. *Journal of Personality 62*, 119-142.
Deci, E. L., Olafsen, A. H. & Ryan, R. M. (2017). Self-Determination Theory in Work Organizations: The State of a Science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*(1), 19-43.
Deci, E. L. & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. London: Plenum.
Deci, E. L. & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry, 11*(4), 227-268.
Deci, E. L. & Ryan, R. M. (2008a). Facilitating optimal motivation and psychological well-being across life's domains. *Canadian Psychology, 49*(1), 14-23.
Deci, E. L. & Ryan, R. M. (2008b). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology, 49*(3), 182-185.
Diabetes UK. (2012). Diabetes in the UK 2012. UK: Diabetes UK.
Diabetes UK. (2014). Diabetes: Facts and Stats. London, UK: Diabetes UK.
Diabetes UK. (2018). Number of people living with diabetes doubles in twenty years. Retrieved 30th May, 2018, from https://www.diabetes.org.uk/about_us/news/diabetes-prevalence-statistics
Diabetes.co.uk. (2015). Blood Vessels. Retrieved 13th March, 2015, from http://www.diabetes.co.uk/body/blood-vessels.html
DiClemente, R. J., Crosby, R. A. & Kegler, M. C. (2009). *Emerging theories in health promotion practice and research* (2nd ed.). San Francisco, California: Jossey-Bass.

Dishman, R. K., Motl, R. W., Sallis, J. F., Dunn, A. L., Birnbaum, A. S., Welk, G. J., . . . Jobe, J. B. (2005). Self-Management Strategies Mediate Self-Efficacy and Physical Activity. *American Journal of Preventive Medicine, 29*(1), 10-18.

Dombrowski, S. U., Avenell, A. & Sniehotta, F. F. (2010). Behavioural Interventions for Obese Adults with Additional Risk Factors for Morbidity: Systematic Review of Effects on Behaviour, Weight and Disease Risk Factors. *Obesity Facts, 3*(6), 377-396.

Dombrowski, S. U., O'Carroll, R. E. & Williams, B. (2016). Form of delivery as a key 'active ingredient' in behaviour change interventions. *British Journal of Health Psychology, 21*(4), 733-740.

Dombrowski, S. U., Sniehotta, F. F., Avenell, A., Johnston, M., MacLennan, G. & Araújo-Soares, V. (2012). Identifying active ingredients in complex behavioural interventions for obese adults with obesity-related co-morbidities or additional risk factors for co-morbidities: a systematic review. *Health Psychology Review, 6*(1), 7-32.

Domínguez-Rodrigo, M. (2002). Hunting and Scavenging by Early Humans: The State of the Debate. *Journal of World Prehistory, 16*(1), 1-54.

Drewnowski, A. & Almiron-Roig, E. (2010). Human Perceptions and Preferences for Fat-Rich Foods. In J. P. Montmayeur & J. le Coutre (Eds.), *Fat Detection: Taste, Texture, and Post Ingestive Effects.* (pp. 265-294). Boca Raton: CRC Press.

Drewnowski, A., Mennella, J. A., Johnson, S. L. & Bellisle, F. (2012). Sweetness and food preference. *The Journal of Nutrition, 142*(6), 1142S-1148S.

Drewnowski, A. & Specter, S. E. (2004). Poverty and obesity: the role of energy density and energy costs. *American Journal of Clinical Nutrition, 79*(1), 6-16.

Eaton, S. B., Cordain, L. & Lindeberg, S. (2002). Evolutionary health promotion: a consideration of common counterarguments. *Preventive Medicine, 34*(2), 119-123.

Eaton, S. B. & Eaton, S. B. I. (2003). An evolutionary perspective on human physical activity: implications for health. *Comparative Biochemistry and Physiology, 136*(1), 153-159.

Eaton, S. B. & Konner, M. (1985). Paleolithic Nutrition: A consideration of its nature and currecnt implications. *The New England Journal of Medicine, 312*, 283-289.

Eaton, S. B., Konner, M. & Cordain, L. (2010). Diet-dependent acid load, Paleolithic nutrition, and evolutionary health promotion. *The American Journal of Clinical Nutrition, 91*(2), 295-297.

Eaton, S. B., Konner, M. & Shostak, M. (1988). Stone agers in the fast lane: Chronic degenerative diseases in evolutionary perspective. *The American Journal of Medicine, 84*(4), 739-749.

Eaton, S. B., Shostak, M. & Konner, M. (1988). *The Paleolithic Prescription: A Program of Diet & Exercise and a Design for Living*: Harper & Row.

Eaton, S. B., Strassman, B. I., Nesse, R. M., Neel, J. V., Ewald, P. W., Williams, G. C., . . . Cordain, L. (2002). Evolutionary health promotion. *Prev Med, 34*(2), 109-118.

Ekelund, U., Ward, H. A., Norat, T., Luan, J. a., May, A. M., Weiderpass, E., . . . Riboli, E. (2015). Physical activity and all-cause mortality across levels of overall and abdominal adiposity in European men and women: the European Prospective Investigation into Cancer and Nutrition Study (EPIC). *The American Journal of Clinical Nutrition*.

Elliott, R. (2003). Executive functions and their disorders: Imaging in clinical neuroscience. *British Medical Bulletin, 65*(1), 49-59.

Ezzati, M., Vander Hoorn, S., Lawes, C. M. M., Leach, R., James, W. P. T., Lopez, A. D., . . . Murray, C. J. L. (2005). Rethinking the "Diseases of Affluence" Paradigm: Global Patterns of Nutritional Risks in Relation to Economic Development. *PLoS Med, 2*(5), e133.

FAO. (2001). Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation. Rome: Food and Agriculture Organization of the United Nations.

Fife-Schaw, C. & Abraham, C. (2009). How much behaviour change should we expect from health promotion campaigns targeting cognitions? An approach to pre-intervention assessment. *Psychology & Health, 24*(7), 763-776.
Fishbein, M. & Ajzen, I. (1975). *Belief, attitude, intention and behavior: an introduction to theory and research*. Reading, MA: Addison Wesley.
Fishbein, M. & Cappella, J. N. (2006). The Role of Theory in Developing Effective Health Communications. *Journal of Communication, 56*(S1), S1-S17.
Fishbein, M. & Yzer, M. C. (2003). Using Theory to Design Effective Health Behavior Interventions. *Communication Theory, 13*(2), 164-183.
Fitzgibbon, M., Gans, K. M., Evans, W. D., Viswanath, K., Johnson-Taylor, W. L., Krebs-Smith, S. M., . . . Yaroch, A. L. (2007). Communicating Healthy Eating: Lessons Learned and Future Directions. *Journal of Nutrition Education and Behavior, 39*(2, Supplement), S63-S71.
Fonseca-Azevedo, K. & Herculano-Houzel, S. (2012). Metabolic constraint imposes tradeoff between body size and number of brain neurons in human evolution. *Proceedings of the National Academy of Sciences of the USA, 109*(45), 18571-18576.
Frank, L. B., Murphy, S. T., Chatterjee, J. S., Moran, M. B. & Baezconde-Garbanati, L. (2015). Telling Stories, Saving Lives: Creating Narrative Health Messages. *Health Communication, 30*(2), 154-163.
Fraser, J., Smith, F. & Bostock, Y. (1997). Pretesting Health Promotion Leaflets—A Case Study. *International Journal of Health Education, 35*(3), 97-101.
Frassetto, L. A., Schloetter, M., Mietus-Synder, M., Morris, R. C., Jr. & Sebastian, A. (2009). Metabolic and physiologic improvements from consuming a paleolithic, hunter-gatherer type diet. *European Journal of Clinical Nutrition, 63*(8), 947-955.
Frieden, T. R. (2010). A Framework for Public Health Action: The Health Impact Pyramid. *American Journal of Public Health, 100*(4), 590-595.
Friedewald, W. T., Levy, R. I. & Fredrickson, D. S. (1972). Estimation of the Concentration of Low-Density Lipoprotein Cholesterol in Plasma, Without Use of the Preparative Ultracentrifuge. *Clinical Chemistry, 18*(6), 499.
Frühbeck, G., Toplak, H., Woodward, E., Yumuk, V., Maislos, M. & Oppert, J. M. (2013). Obesity: The Gateway to Ill Health - an EASO Position Statement on a Rising Public Health, Clinical and Scientific Challenge in Europe. *Obesity Facts, 6*(2), 117-120.
Fuller, E., Mindell, J. & Prior, G. (2017). Health Survey for England 2016. London: NHS Digital.
Furnham, A., Gunter, B. & Green, A. (1990). Remembering science: The recall of factual information as a function of the presentation mode. *Applied Cognitive Psychology, 4*(3), 203-212.
Fyfe, C. L., Stewart, J., Murison, S. D., Jackson, D. M., Rance, K., Speakman, J. R., . . . Johnstone, A. M. (2010). Evaluating energy intake measurement in free-living subjects: when to record and for how long? *Public Health Nutrition, 13*(02), 172-180.
Gapminder World. (2018). Wealth & Health of Nations. Retrieved May 31st, 2018, from http://www.gapminder.org/world
Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychology Review, 9*(3), 277-295.
Gardner, B., Abraham, C., Lally, P. & de Bruijn, G.-J. (2012). Towards parsimony in habit measurement: Testing the convergent and predictive validity of an automaticity subscale of the Self-Report Habit Index. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 1-12.
Garn, S. M. & Leonard, W. R. (1989). What did our ancestors eat? *Nutrition Reviews, 47*(11), 337-345.

Gazmararian, J. A., Curran, J. W., Parker, R. M., Bernhardt, J. M. & DeBuono, B. A. (2005). Public health literacy in America: An ethical imperative. *American Journal of Preventive Medicine, 28*(3), 317-322.
Gettler, L. T. & McKenna, J. J. (2011). Evolutionary perspectives on mother–infant sleep proximity and breastfeeding in a laboratory setting. *American Journal of Physical Anthropology, 144*(3), 454-462.
Gigerenzer, G. (2010). Personal Reflections on Theory and Psychology. *Theory & Psychology, 20*(6), 733-743.
Gillison, F., Stathi, A., Reddy, P., Perry, R., Taylor, G., Bennett, P., . . . Greaves, C. (2015). Processes of behavior change and weight loss in a theory-based weight loss intervention program: a test of the process model for lifestyle behavior change. *International Journal of Behavioral Nutrition and Physical Activity, 12*(1), 1-15.
Glanz, K. & Bishop, D. B. (2010). The Role of Behavioral Science Theory in Development and Implementation of Public Health Interventions. *Annual Review of Public Health, 31*(1), 399-418.
Glanz, K. & Rimer, B. K. (2005). Theory at a Glance: A guide for health promotion practice (2nd ed.). Maryland, US: National Institutes of Health.
Glasgow, R. E., Klesges, L. M., Dzewaltowski, D. A., Bull, S. S. & Estabrooks, P. (2004). The future of health behavior change research: What is needed to improve translation of research into health promotion practice? *Annals of Behavioral Medicine, 27*(1), 3-12.
Goldberg, J. P. (1992). Nutrition and Health Communication: The Message and the Media Over Half a Century. *Nutrition Reviews, 50*(3), 71-77.
Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist, 54*(7), 493-503.
Google Inc. (2017). Google Analytics. Online https://www.google.co.uk/analytics: Google Inc.
Google Trends. (2014). Explore: Diet. Retrieved October 10, 2014, from Google http://www.google.com/trends/explore#q=diet&date=1%2F2013%2012m&cmpt=q
Google Trends. (2016). Explore: Paleo diet. Retrieved April 2016, from Google https://www.google.co.uk/trends/explore#q=paleo%20diet
Greaves, C., Gillison, F., Stathi, A., Bennett, P., Reddy, P., Dunbar, J., . . . Taylor, G. (2015). Waste the waist: a pilot randomised controlled trial of a primary care based intervention to support lifestyle change in people with high cardiovascular risk. *International Journal of Behavioral Nutrition and Physical Activity, 12*(1), 1.
Greaves, C., Poltawski, L., Garside, R. & Briscoe, S. (2017). Understanding the challenge of weight loss maintenance: a systematic review and synthesis of qualitative research on weight loss maintenance. *Health Psychology Review, 11*(2), 145-163.
Greaves, C., Sheppard, K., Abraham, C., Hardeman, W., Roden, M., Evans, P., . . . Group, T. I. S. (2011). Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. *BMC Public Health, 11*(1), 119.
Greaves, C. J. (2015). Uptake of Behavior Change Techniques - a Key Focus for Process Analysis and for Intervention Delivery: a Comment on Hankonen et al. *Annals of Behavioral Medicine, 49*(1), 1-2.
Green, D. (2014). *The Paleo Diet: Food your body is designed to eat*. London, UK: Kyle Books.
Green, L. & Kreuter, M. W. (2005). *Health promotion planning: An educational and ecological approach (4th ed.)* (4th ed.). Mountain View, CA: Mayfield Publishers.
Green, M. C. (2004). Transportation Into Narrative Worlds: The Role of Prior Knowledge and Perceived Realism. *Discourse Processes, 38*(2), 247-266.
Green, M. C. & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology, 79*(5), 701-721.

Guyenet, S. J. (2015, March 6, 2015). Food reward Friday: Donuts. Retrieved from http://wholehealthsource.blogspot.co.uk/2015/03/food-reward-friday.html#more
Guyenet, S. J. & Schwartz, M. W. (2012). Clinical review: Regulation of food intake, energy balance, and body fat mass: implications for the pathogenesis and treatment of obesity. *The Journal of Clinical Endocrinology and Metabolism, 97*(3), 745-755.
Haase, A., Steptoe, A., Sallis, J. F. & Wardle, J. (2004). Leisure-time physical activity in university students from 23 countries: associations with health beliefs, risk awareness, and national economic development. *Preventive Medicine, 39*(1), 182-190.
Hagger, M. S., Chatzisarantis, N. L. & Biddle, S. J. (2002). A meta-analytic review of the theories of reasoned action and planned behavior in physical activity: Predictive validity and the contribution of additional variables. *Journal of Sport & Exercise Psychology, 24*(1), 3-32.
Halaas, J. L., Gajiwala, K. S., Maffei, M., Cohen, S. L., Chait, B. T., Rabinowitz, D., . . . Friedman, J. M. (1995). Weight-reducing effects of the plasma protein encoded by the obese gene. *Science, 269*(5223), 543-546.
Hales, C. N. & Barker, D. J. P. (1992). Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. *Diabetologia, 35*(7), 595-601.
Hamilton, M. T., Healy, G. N., Dunstan, D. W., Zderic, T. W. & Owen, N. (2008). Too Little Exercise and Too Much Sitting: Inactivity Physiology and the Need for New Recommendations on Sedentary Behavior. *Current cardiovascular risk reports, 2*(4), 292-298.
Hardeman, W., Sutton, S., Griffin, S., Johnston, M., White, A., Wareham, N. J. & Kinmonth, A. L. (2005). A causal modelling approach to the development of theory-based behaviour change programmes for trial evaluation. *Health Education Research, 20*(6), 676-687.
Harris, T., Kerry, S. M., Limb, E. S., Victor, C. R., Iliffe, S., Ussher, M., . . . Cook, D. G. (2017). Effect of a Primary Care Walking Intervention with and without Nurse Support on Physical Activity Levels in 45- to 75-Year-Olds: The Pedometer And Consultation Evaluation (PACE-UP) Cluster Randomised Clinical Trial. *PLOS Medicine, 14*(1), e1002210.
Hartley, J. (2012). Designing Easy-to-Read Text. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.
Haskell, W. L., Lee, I., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical Activity and Public Health: Updated Recommendation for Adults from the American College of Sports Medicine and the American Heart Association. *Medicine & Science in Sports & Exercise, 39*(8), 1423-1434.
Hassandra, M., Goudas, M. & Chroni, S. (2003). Examining factors associated with intrinsic motivation in physical education: a qualitative approach1. *Psychology of Sport and Exercise, 4*(3), 211-223.
Havel, P. J. (2000). Role of adipose tissue in body-weight regulation: mechanisms regulating leptin production and energy balance. *Proceedings of the Nutrition Society, 59*(03), 359-371.
Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: a regression-based approach*. London: Guilford Press.
Hayflick, L. (1998). How and why we age. *Experimental Gerontology, 33*(7–8), 639-653.
Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z. & Owen, N. (2008). Objectively Measured Sedentary Time, Physical Activity, and Metabolic Risk: The Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care, 31*(2), 369-371.
Hegarty, M. (2004). Dynamic visualizations and learning: getting to the difficult questions. *Learning and Instruction, 14*(3), 343-351.

Hex, N., Bartlett, C., Wright, D., Taylor, M. & Varley, D. (2012). Estimating the current and future costs of Type 1 and Type 2 diabetes in the UK, including direct health costs and indirect societal and productivity costs. *Diabetic Medicine, 29*(7), 855-862.

Hinyard, L. J. & Kreuter, M. W. (2007). Using Narrative Communication as a Tool for Health Behavior Change: A Conceptual, Theoretical, and Empirical Overview. *Health Education & Behavior, 34*(5), 777-792.

HM Government. (2008). *Healthy Weight, Healthy Lives: a Cross-Government Strategy for England*. London, UK: Crown.

HM Government. (2010). *Healthy Lives, Healthy People: Our strategy for public health in England*. UK: Crown.

Höffler, T. N. & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17*(6), 722-738.

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., . . . Michie, S. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal, 348*.

Hopkins, W. G. (2010). A Spreadsheet to Reduce Differences Between Group Means of Subject Characteristics in a Controlled Trial: Minimize means as recruit. http://www.sportsci.org/2010/wghminim.htm#_Spreadsheets_for_Minimization.

Hopkins, W. G., Marshall, S. W., Batterham, A. M. & Hanin, J. (2009). Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise, 41*(1), 3-12.

Hotjar Ltd. (2017). Hotjar (Version 3.0). Online https://www.hotjar.com/: Hotjar Ltd.

Houts, P. S., Doak, C. C., Doak, L. G. & Loscalzo, M. J. (2006). The role of pictures in improving health communication: A review of research on attention, comprehension, recall, and adherence. *Patient Education and Counseling, 61*(2), 173-190.

Hsieh, H.-F. & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research, 15*(9), 1277-1288.

Hu, F. B. (2011). Globalization of Diabetes: The role of diet, lifestyle, and genes. *Diabetes Care, 34*(6), 1249-1257.

Hwang, K. O., Ottenbacher, A. J., Green, A. P., Cannon-Diehl, M. R., Richardson, O., Bernstam, E. V. & Thomas, E. J. (2010). Social support in an Internet weight loss community. *International Journal of Medical Informatics, 79*(1), 5-13.

Hyman, D. J., Pavlik, V. N., Taylor, W. C., Goodrick, G. & Moye, L. (2007). Simultaneous vs sequential counseling for multiple behavior change. *Archives of Internal Medicine, 167*(11), 1152-1158.

Ibrahim, M. M. (2010). Subcutaneous and visceral adipose tissue: structural and functional differences. *Obesity Reviews, 11*(1), 11-18.

Igartua, J.-J. & Vega Casanova, J. (2016). Identification With Characters, Elaboration, and Counterarguing in Entertainment-Education Interventions Through Audiovisual Fiction. *Journal of Health Communication, 21*(3), 293-300.

Ingram, C. J., Mulcare, C. A., Itan, Y., Thomas, M. G. & Swallow, D. M. (2009). Lactose digestion and the evolutionary genetics of lactase persistence. *Human Genetics, 124*(6), 579-591.

Janssen, I., Katzmarzyk, P. T. & Ross, R. (2002). Body Mass Index, Waist Circumference, and Health Risk: Evidence in support of Current *Archives of Internal Medicine, 162*(18), 6.

Johannsen, D. L., Calabro, M. A., Stewart, J., Franke, W., Rood, J. C. & Welk, G. J. (2010). Accuracy of Armband Monitors for Measuring Daily Energy Expenditure in Healthy Adults. *Medicine & Science in Sports & Exercise, 42*(11), 2134-2140.

Johns, D. J., Hartmann-Boyce, J., Jebb, S. A. & Aveyard, P. (2014). Diet or Exercise Interventions vs Combined Behavioral Weight Management Programs: A Systematic Review and

Meta-Analysis of Direct Comparisons. *Journal of the Academy of Nutrition and Dietetics, 114*(10), 1557-1568.
Johnson, F., Cooke, L., Croker, H. & Wardle, J. (2008). *Changing perceptions of weight in Great Britain: comparison of two population surveys* (Vol. 337).
Jones, L. W., Sinclair, R. C. & Courneya, K. S. (2003). The effects of source credibility and message framing on exercise intentions, behaviors, and attitudes: An integration of the elaboration likelihood model and prospect theory. *Journal of Applied Social Psychology, 33*(1), 179-196.
Jonsson, T., Granfeldt, Y., Ahren, B., Branell, U. C., Palsson, G., Hansson, A., . . . Lindeberg, S. (2009). Beneficial effects of a Paleolithic diet on cardiovascular risk factors in type 2 diabetes: a randomized cross-over pilot study. *Cardiovasc Diabetol, 8*, 35.
Jonsson, T., Granfeldt, Y., Lindeberg, S. & Hallberg, A.-C. (2013). Subjective satiety and other experiences of a Paleolithic diet compared to a diabetes diet in patients with type 2 diabetes. *Nutrition Journal, 12*(1), 105.
Kahn, S. E. (2003). The relative contributions of insulin resistance and beta-cell dysfunction to the pathophysiology of Type 2 diabetes. *Diabetologia, 46*(1), 3-19.
Kahneman, D. (2011). *Thinking, fast and slow*. London: Allen Lane.
Kaplan, H., Hill, K., Lancaster, J. & Hurtado, A. M. (2000). A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology: Issues, News, and Reviews, 9*(4), 156-185.
Karlsson, P. & Bergmark, A. (2015). Compared with what? An analysis of control-group types in Cochrane and Campbell reviews of psychosocial treatment efficacy with substance use disorders. *Addiction, 110*(3), 420-428.
Karoliina. (2011). If distance running is so bad for us, why does it feel so good? [online forum comment]. 2015, from https://www.paleohacks.com/running/if-distance-running-is-so-bad-for-us-why-does-it-feel-so-good-9913
Katz, D. L. (2005). Competing dietary claims for weight loss: Finding the Forest Through Truculent Trees. *Annual Review of Public Health, 26*(1), 61-88.
Katz, I., Assor, A., Kanat-Maymon, Y. & Bereby-Meyer, Y. (2006). Interest as a Motivational Resource: Feedback and Gender Matter, but Interest Makes the Difference. *Social Psychology of Education, 9*(1), 27-42.
Kelley, J. M., Kraft-Todd, G., Schapira, L., Kossowsky, J. & Riess, H. (2014). The Influence of the Patient-Clinician Relationship on Healthcare Outcomes: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *PLOS ONE, 9*(4), e94207.
Keskitalo, K., Knaapila, A., Kallela, M., Palotie, A., Wessman, M., Sammalisto, S., . . . Perola, M. (2007). Sweet taste preferences are partly genetically predetermined: identification of a trait locus on chromosome 16. *The American Journal of Clinical Nutrition, 86*, 55-63.
King, A., Castro, C., Buman, M., Hekler, E., Urizar, G., Jr. & Ahn, D. (2013). Behavioral Impacts of Sequentially versus Simultaneously Delivered Dietary Plus Physical Activity Interventions: the CALM Trial. *Annals of Behavioral Medicine, 46*(2), 157-168.
King, A. C., Blair, S. N., Bild, D. E., Dishman, R. K., Dubbert, P. M., Marcus, B. H., . . . Yeager, K. K. (1992). Determinants of physical activity and interventions in adults. *Medicine & Science in Sports & Exercise, 24*(S6), S221-S236.
Klein, R. G. (1995). Anatomy, Behavior, and Modern Human Origins. *Journal of World Prehistory, 9*(2), 167-198.
Knox, E. C. L., Esliger, D. W., Biddle, S. J. H. & Sherar, L. B. (2013). Lack of knowledge of physical activity guidelines: can physical activity promotion campaigns do better? *BMJ Open, 3*(12).
Kohl, L. F. M., Crutzen, R. & de Vries, N. K. (2013). Online Prevention Aimed at Lifestyle Behaviors: A Systematic Review of Reviews. *Journal of Medical Internet Research, 15*(7), e146.

Kok, G. & de Vries, N. K. (2015). Health Education and Health Promotion *International Encyclopedia of the Social & Behavioral Sciences* (2nd ed., pp. 620-627). Oxford: Elsevier.

Kok, G., Schaalma, H., Ruiter, R. A. C., Van Empelen, P. & Brug, J. (2004). Intervention Mapping: Protocol for Applying Health Psychology Theory to Prevention Programmes. *Journal of Health Psychology, 9*(1), 85-98.

Konner, M. & Eaton, S. B. (2010). Paleolithic nutrition: twenty-five years later. *Nutrition in Clinical Practice, 25*(6), 594-602.

Kools, M. (2012). Making Written Materials Easy to Understand. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.

Kreuter, M. W., Strecher, V. J. & Glassman, B. (1999). One size does not fit all: The case for tailoring print materials. *Annals of Behavioral Medicine, 21*(4), 276-283.

Kuipers, R. S., Joordens, J. C. A. & Muskiet, F. A. J. (2012). A multidisciplinary reconstruction of Palaeolithic nutrition that holds promise for the prevention and treatment of diseases of civilisation. *Nutrition Research Reviews, 25*(1), 96-129.

Kwasnicka, D., Dombrowski, S. U., White, M. & Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health Psychology Review*, 1-39.

Laird, N. (1983). Further Comparative Analyses of Pretest-Posttest Research Designs. *The American Statistician, 37*(4), 329-330.

Laitner, M. H., Minski, S. A. & Perri, M. G. (2016). The role of self-monitoring in the maintenance of weight loss success. *Eating Behaviors, 21*, 193-197.

Lally, P. & Gardner, B. (2013). Promoting habit formation. *Health Psychology Review, 7*(sup1), S137-S158.

Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W. & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology, 40*(6), 998-1009.

Lambert, T. (2014). A Brief History of Food. Retrieved May 25, 2015, from http://www.localhistories.org/food.html

Lazarus, R. S. (1991). Cognition and motivation in emotion. *American Psychologist, 46*(4), 352-367.

Leblanc, V., Bégin, C., Hudon, A.-M., Royer, M.-M., Corneau, L., Dodin, S. & Lemieux, S. (2016). Effects of a nutritional intervention program based on the self-determination theory and promoting the Mediterranean diet. *Health Psychology Open, 3*(1), 2055102915622094.

Leonard, W. R. (2008). Lifestyle, diet and disease: Comparative perspectives on the determinants of chronic health risks. In S. C. Stearns & J. C. Koella (Eds.), *Evolution in health and disease* (2nd ed., pp. 265-276). Oxford: Oxford University Press.

Leonard, W. R. (2010). Size Counts: Evolutionary Perspectives on Physical Activity and Body Size From Early Hominids to Modern Humans. *Journal of Physical Activity & Health, 7*, S284-S298.

Levine, J. A., McCrady, S. K., Boyne, S., Smith, J., Cargill, K. & Forrester, T. (2011). Non-exercise Physical Activity in Agricultural and Urban People. *Urban Studies, 48*(11), 2417-2427.

Lieberman, D. E. (2013). *The Story of the Human Body: Evolution, Health, and Disease*. London, UK: Penguin

Lieberman, L. S. (2006). Evolutionary and anthropological perspectives on optimal foraging in obesogenic environments. *Appetite, 47*(1), 3-9.

Liener, I. E. (1962). Toxic factors in edible legumes and their elimination. *The American Journal of Clinical Nutrition, 1*, 281.

Lindeberg, S., Eliasson, M., Lindahl, B. & Ahren, B. (1999). Low serum insulin in traditional Pacific Islanders--the Kitava Study. *Metabolism, 48*(10), 1216-1219.
Lindeberg, S., Jonsson, T., Granfeldt, Y., Borgstrand, E., Soffman, J., Sjostrom, K. & Ahren, B. (2007). A Palaeolithic diet improves glucose tolerance more than a Mediterranean-like diet in individuals with ischaemic heart disease. *Diabetologia, 50*(9), 1795-1807.
Livesey, G., Taylor, R., Hulshof, T. & Howlett, J. (2008). Glycemic response and health—a systematic review and meta-analysis: relations between dietary glycemic properties and health outcomes. *The American Journal of Clinical Nutrition, 87*(1), 258S-268S.
Logan, A., Katzman, M. & Balanza-Martinez, V. (2015). Natural environments, ancestral diets, and microbial ecology: is there a modern "paleo-deficit disorder"? Part I. *Journal of Physiological Anthropology, 34*(1), 1.
Lorenc, T., Petticrew, M., Welch, V. & Tugwell, P. (2013). What types of interventions generate inequalities? Evidence from systematic reviews. *Journal of Epidemiology and Community Health, 67*(2), 190-193.
Louis, M. R. & Sutton, R. I. (1991). Switching Cognitive Gears: From Habits of Mind to Active Thinking. *Human Relations, 44*(1), 55-76.
Luca, F., Perry, G. H. & Di Rienzo, A. (2010). Evolutionary Adaptations to Dietary Changes. *Annual Review of Nutrition, 30*(1), 291-314.
Marcus, B. H., Williams, D. M., Dubbert, P. M., Sallis, J. F., King, A. C., Yancey, A. K., . . . Claytor, R. P. (2006). Physical Activity Intervention Studies: What We Know and What We Need to Know. *Circulation, 114*(24), 2739-2752.
Markland, D. (2014). Exercise Motivation Measurement: The Behavioural Regulation in Exercise Questionnaire. Retrieved November, 2015, from http://pages.bangor.ac.uk/~pes004/exercise_motivation/breq/breq.htm
Markland, D. & Tobin, V. (2004). A Modification to the Behavioural Regulation in Exercise Questionnaire to Include an Assessment of Amotivation. *Journal of Sport & Exercise Psychology, 26*(2), 191-196.
Mars, M., de Graaf, C., de Groot, L. C. & Kok, F. J. (2005). Decreases in fasting leptin and insulin concentrations after acute energy restriction and subsequent compensation in food intake. *The American Journal of Clinical Nutrition, 81*(3), 570-577.
Matthews, D. R., Hosker, J. P., Rudenski, A. S., Naylor, B. A., Treacher, D. F. & Turner, R. C. (1985). Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia, 28*(7), 412-419.
McAuley, E. (1992). The role of efficacy cognitions in the prediction of exercise behavior in middle-aged adults. *Journal of Behavioral Medicine, 15*(1), 65-88.
McCance, D. R., Pettitt, D. J., Hanson, R. L., Jacobsson, L. T. H., Knowler, W. C. & Bennett, P. H. (1994). Birth weight and non-insulin dependent diabetes: thrifty genotype, thrifty phenotype, or surviving small baby genotype? *British Medical Journal, 308*(6934), 942-945.
McEachan, R. R. C., Conner, M., Taylor, N. J. & Lawton, R. J. (2011). Prospective prediction of health-related behaviours with the Theory of Planned Behaviour: a meta-analysis. *Health Psychology Review, 5*(2), 97-144.
McGinnis, J. & Foege, W. H. (1993). Actual causes of death in the united states. *JAMA, 270*(18), 2207-2212.
McGuire, W. J. (1999). *Constructing social psychology: creative and critical processes*. Cambridge, UK: Cambridge University Press.
McKinlay, J. B. (1995). The New Public Health Approach to Improving Physical Activity and Autonomy in Older Populations. In E. Heikkinen, J. Kuusinen & I. Ruoppila (Eds.), *Preparation for Aging* (pp. 87-103). Boston, MA: Springer.

Medical Research Council. (2015). Obesity research priorities. Retrieved April 13, 2015, from http://www.mrc.ac.uk/research/initiatives/obesity-research/obesity-research-priorities/

Meppelink, C. S., van Weert, C. M. J., Haven, J. C. & Smit, G. E. (2015). The Effectiveness of Health Animations in Audiences With Different Health Literacy Levels: An Experimental Study. *Journal of Medical Internet Research, 17*(1), e11.

Meyrick, J. (2006). What is Good Qualitative Research?: A First Step towards a Comprehensive Approach to Judging Rigour/Quality. *Journal of Health Psychology, 11*(5), 799-808.

Michie, S. & Abraham, C. (2004). Interventions to change health behaviours: evidence-based or evidence-inspired? *Psychology & Health, 19*(1), 29-49.

Michie, S., Abraham, C., Whittington, C., McAteer, J. & Gupta, S. (2009). Effective techniques in healthy eating and physical activity interventions: A meta-regression. *Health Psychology, 28*(6), 690-701.

Michie, S., Ashford, S., Sniehotta, F., Dombrowski, S., Bishop, A. & French, D. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychology & Health, 26*(11), 1479-1498.

Michie, S., Campbell, R., Brown, J., West, R. & Gainforth, H. (2014). *ABC of Behaviour Change Theories*. UK: Silverback Publishing.

Michie, S. & Johnston, M. (2013). Behaviour Change Techniques. In M. D. Gellman & J. R. Turner (Eds.), *Encyclopaedia of Behavioural Medicine* (pp. 182 - 187). New York: Springer.

Michie, S., Johnston, M., Francis, J., Hardeman, W. & Eccles, M. (2008). From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour Change Techniques. *Applied Psychology: An International Review, 57*(4), 660-680.

Michie, S. & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology, 29*(1), 1-8.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. (2013). The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Annals of Behavioral Medicine, 46*(1), 81-95.

Michie, S., van Stralen, M. M. & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science, 6*.

Michie, S., Yardley, L., West, R., Patrick, K. & Greaves, F. (2017). Developing and Evaluating Digital Interventions to Promote Behavior Change in Health and Health Care: Recommendations Resulting From an International Workshop. *J Med Internet Res, 19*(6), e232.

Middleton, K. R., Anton, S. D. & Perri, M. G. (2013). Long-Term Adherence to Health Behavior Change. *American journal of lifestyle medicine, 7*(6), 395-404.

Miller, L. M. S., Gibson, T. N., Applegate, E. A. & de Dios, J. (2011). Mechanisms underlying comprehension of health information in adulthood: The roles of prior knowledge and working memory capacity. *Journal of Health Psychology, 16*(5), 794-806.

Miller, W. R. & Rose, G. S. (2009). Toward a Theory of Motivational Interviewing. *American Psychologist, 64*(6), 527-537.

Millward, D. J. (2013). Energy balance and obesity: a UK perspective on the gluttony v. sloth debate. *Nutrition Research Reviews, 26*(02), 89-109.

Mokdad, A. H., Marks, J. S., Stroup, D. F. & Gerberding, J. L. (2004). Actual causes of death in the united states, 2000. *JAMA, 291*(10), 1238-1245.

Moodie, P. M. (1973). *Aboriginal health*. Canberra, Australia: Australian National University Press.

Morton, G. J., Cummings, D. E., Baskin, D. G., Barsh, G. S. & Schwartz, M. W. (2006). Central nervous system control of food intake and body weight. *Nature, 443*(7109), 289-295.
Müller-Riemenschneider, F., Reinhold, T., Nocon, M. & Willich, S. N. (2008). Long-term effectiveness of interventions promoting physical activity: A systematic review. *Preventive Medicine, 47*(4), 354-368.
Naidoo, J. & Wills, J. (2005). *Public health and health promotion: developing practice* (2nd ed.). Edinburgh, UK: Baillière Tindall.
National History Museum. (2015a). Homo heidelbergensis. Retrieved May 24, 2015, from http://www.nhm.ac.uk/nature-online/life/human-origins/early-human-family/homo-heidelbergensis/index.html
National History Museum. (2015b). Where did modern humans come from? Retrieved May 24, 2015, from http://www.nhm.ac.uk/nature-online/life/human-origins/modern-human-evolution/where/index.html
National Institute for Health and Care Excellence. (2014a). Behaviour change: individual approaches. Public health guideline [PH49]: Available at: https://www.nice.org.uk/guidance/ph49.
National Institute for Health and Care Excellence. (2014b). Obesity: identification, assessment and management. Clinical guideline [CG189]: Available at: https://www.nice.org.uk/guidance/cg189.
National Institute for Health and Clinical Excellence. (2007). Behaviour change: the principles for effective interventions. Public health guideline [PH6]: Available at: https://www.nice.org.uk/guidance/ph6.
National Institute for Health and Clinical Excellence. (2010). Cardiovascular disease prevention. Public Health guideline [PH25]: Available at: https://www.nice.org.uk/guidance/ph25.
National Institute for Health and Clinical Excellence. (2012). Preventing type 2 diabetes. Public health guideline [PH38]: Available at: https://www.nice.org.uk/guidance/ph38.
National Institutes of Health. (2002). Making Health Communication Programs Work: A Planner's Guide. Bethesda, US: National Cancer Institute.
Neel, J. V. (1962). Diabetes Mellitus: A “Thrifty” Genotype Rendered Detrimental by “Progress”? *American Journal of Human Genetics, 14*(4), 353-362.
Nesse, R. M. & Stearns, S. C. (2008). The great opportunity: Evolutionary applications to medicine and public health. *Evolutionary Applications, 1*(1), 28-48.
Ng, J. Y. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L. & Williams, G. C. (2012). Self-Determination Theory Applied to Health Contexts: A Meta-Analysis. *Perspectives on Psychological Science, 7*(4), 325-340.
Ng, S. W. & Popkin, B. M. (2012). Time use and physical activity: a shift away from movement across the globe. *Obesity Reviews, 13*(8), 659-680.
NHS Choices. (2014). What's your BMI? Retrieved December 12, 2014, from http://www.nhs.uk/Livewell/loseweight/Pages/BodyMassIndex.aspx#people
NHS Digital. (2018). Statistics on Obesity, Physical Activity and Diet. Surrey, UK: Health and Social Care Information Centre.
NIACE. (2009). Readability: How to produce clear written materials for a range of readers. Leicester, UK: National Institute of Adult Continuing Education.
Niederdeppe, J., Shapiro, M. A., Kim, H., Bartolo, D. & Porticella, N. (2014). Narrative Persuasion, Causality, Complex Integration, and Support for Obesity Policy. *Health Communication, 29*(5), 431-444.
Noar, S. M., Benac, C. N. & Harris, M. S. (2007). Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. *Psychological Bulletin, 133*(4), 673-693.

Norman, G. J., Carlson, J. A., Sallis, J. F., Wagner, N., Calfas, K. J. & Patrick, K. (2010). Reliability and validity of brief psychosocial measures related to dietary behaviors. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 56.
Nunn, C., L., Wallace, I. & Beall, C., M. (2015). Connecting evolution, medicine, and public health. *Evolutionary Anthropology: Issues, News, and Reviews, 24*(4), 127-129.
Nurmi, J., Hagger, M. S., Haukkala, A., Araújo-Soares, V. & Hankonen, N. (2016). Relations Between Autonomous Motivation and Leisure-Time Physical Activity Participation: The Mediating Role of Self-Regulation Techniques. *Journal of Sport and Exercise Psychology, 38*(2), 128-137.
Nutbeam, D. (2000). Health literacy as a public health goal: a challenge for contemporary health education and communication strategies into the 21st century. *Health Promotion International, 15*(3), 259-267.
O'Brien, H. L. & Toms, E. G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. *Journal of the American Society for Information Science and Technology, 59*(6), 938-955.
O'Dea, K. (1984). Marked improvement in carbohydrate and lipid meatbolism in diabetic Australian aborigines after temporary reversion to traditional lifestyle. *Diabetes, 33*, 596-603.
O'Dea, K., Spargo, R. M. & Nestel, P. J. (1982). Impact of Westernization on carbohydrate and lipid metabolism in Australian Aborigines. *Diabetologia, 22*(3), 148-153.
Oakley, N. (2015, January 8). Which is the best diet to follow for weight loss? Reviews of Atkins, 5:2, Weightwatchers, Slimming World and more. *The Mirror*. Retrieved from http://www.mirror.co.uk/lifestyle/dieting/best-diet-follow-weight-loss-4935386
OECD. (2015). Adult education level. Retrieved September, 2015, from https://data.oecd.org/eduatt/adult-education-level.htm
OECD. (2018). Adult education level Retrieved January, 2018, from https://data.oecd.org/eduatt/adult-education-level.htm#indicator-chart
Oliver, W. J., Cohen, E. L. & Neel, J. V. (1975). Blood pressure, sodium intake, and sodium related hormones in the Yanomamo Indians, a "no-salt" culture. *Circulation, 52*(1), 146-151.
Orbell, S. & Sheeran, P. (1998). 'Inclined abstainers': A problem for predicting health-related behaviour. *British Journal of Social Psychology, 37*(2), 151-165.
Ory, M. G., Smith, M. L., Mier, N. & Wernicke, M. M. (2010). The Science of Sustaining Health Behavior Change: The Health Maintenance Consortium. *American journal of health behavior, 34*(6), 647-659.
Osterdahl, M., Kocturk, T., Koochek, A. & Wandell, P. E. (2008). Effects of a short-term intervention with a paleolithic diet in healthy volunteers. *European Journal of Clinical Nutrition, 62*(5), 682-685.
Otten, J., Stomby, A., Waling, M., Isaksson, A., Tellström, A., Lundin-Olsson, L., . . . Olsson, T. (2017). Benefits of a Paleolithic diet with and without supervised exercise on fat mass, insulin sensitivity, and glycemic control: a randomized controlled trial in individuals with type 2 diabetes. *Diabetes/Metabolism Research and Reviews, 33*(1), e2828-n/a.
Owen, N., Healy, G. N., Matthews, C. E. & Dunstan, D. W. (2010). Too Much Sitting: The Population-Health Science of Sedentary Behavior. *Exercise and Sport Sciences Reviews, 38*(3), 105-113.
Oxford Dictionaries. (2015a). *"Culture"*. Oxford University Press.
Oxford Dictionaries. (2015b). *"Natural selection"*. Oxford University Press.
Painter, J., Borba, C., Hynes, M., Mays, D. & Glanz, K. (2008). The Use of Theory in Health Behavior Research from 2000 to 2005: A Systematic Review. *Annals of Behavioral Medicine, 35*(3), 358-362.

Parmenter, K., Waller, J. & Wardle, J. (2000). Demographic variation in nutrition knowledge in England. *Health Education Research, 15*(2), 163-174.

Parrott, R. L. (1995). Motivation to Attend to Health Messages. In E. Maibach & R. L. Parrott (Eds.), *Designing health messages : approaches from communication theory and public health practice*. London: Sage.

Pastore, R. L., Brooks, J. T. & Carbone, J. W. (2015). Paleolithic nutrition improves plasma lipid concentrations of hypercholesterolemic adults to a greater extent than traditional heart-healthy dietary recommendations. *Nutrition Research, 35*(6), 474-479.

Patall, E. A., Dent, A. L., Oyer, M. & Wynn, S. R. (2013). Student autonomy and course value: The unique and cumulative roles of various teacher practices. *Motivation and Emotion, 37*(1), 14-32.

Patrick, H. & Williams, G. C. (2012). Self-determination theory: its application to health behavior and complementarity with motivational interviewing. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 18.

Patterson, R. E., Satia, J. A., Kristal, A. R., Neuhouser, M. L. & Drewnowski, A. (2001). Is There a Consumer Backlash Against the Diet and Health Message? *Journal of the American Dietetic Association, 101*(1), 37-41.

Pawlak, R. & Colby, S. (2009). Benefits, barriers, self-efficacy and knowledge regarding healthy foods; perception of African Americans living in eastern North Carolina. *Nutrition Research and Practice, 3*(1), 56-63.

Pelletier, L., Dion, S., Slovinec-D'Angelo, M. & Reid, R. (2004). Why Do You Regulate What You Eat? Relationships Between Forms of Regulation, Eating Behaviors, Sustained Dietary Behavior Change, and Psychological Adjustment. *Motivation and Emotion, 28*(3), 245-277.

Peppa, M., Uribarri, J. & Vlassara, H. (2003). Glucose, Advanced Glycation End Products, and Diabetes Complications: What Is New and What Works. *Clinical Diabetes, 21*(4), 186-187.

Petty, R. E., Barden, J. & Wheeler, S. C. (2009). The elaboration likelihood model of persuasion: Health promotions that yield sustained behavioral change. In R. J. DiClemente, R. A. Crosby & M. C. Kegler (Eds.), *Emerging theories in health promotion practice and research* (2nd ed., pp. 185-214). San Francisco: Jossey-Bass.

Petty, R. E. & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of Persuasion. *Advances in Experimental Social Psychology, 19*, 123-205.

Petty, R. E., Heesacker, M. & Hughes, J. N. (1997). The elaboration likelihood model: Implications for the practice of school psychology. *Journal of School Psychology, 35*(2), 107-136.

Petty, R. E., Kasmer, J. A., Haugtvedt, C. P. & Cacioppo, J. T. (1987). Source and message factors in persuasion: A reply to Stiff's critique of the Elaboration Likelihood Model. *Communication Monographs, 54*, 233-249.

Piggin, J. (2012). Turning health research into health promotion: A study of causality and 'critical insights' in a United Kingdom health campaign. *Health Policy, 107*(2–3), 296-303.

Piggin, J. & Lee, J. (2011). 'Don't mention obesity': Contradictions and tensions in the UK Change4Life health promotion campaign. *Journal of Health Psychology, 16*(8), 1151-1164.

Pollan, M. (2008). *In Defence of Food*. London, UK: Penguin.

Pope, C., Ziebland, S. & Mays, N. (2000). Analysing qualitative data. *British Medical Journal, 320*(7227), 114-116.

Potts, R. (2003). Environmental variability and its impact on adaptive evolution, with special reference to human origins. In L. Rothschild & A. Lister (Eds.), *Evolution on Planet Earth: Impact of the physical environment* (pp. 363 - 378). London: Academic Press.

Power, M. L. & Schulkin, J. (2009). *The Evolution of Obesity*. Baltimore, Maryland: Johns Hopkins University Press.

Presset, B., Laurenczy, B., Malatesta, D. & Barral, J. (2018). Accuracy of a smartphone pedometer application according to different speeds and mobile phone locations in a laboratory context. *Journal of Exercise Science & Fitness, 16*(2), 43-48.

Prestwich, A., Sniehotta, F. F., Whittington, C., Dombrowski, S. U., Rogers, L. & Michie, S. (2014). Does theory influence the effectiveness of health behavior interventions? Meta-analysis. *Health Psychology, 33*(5), 465-474.

Protheroe, J., Estacio, E. V. & Saidy-Khan, S. (2015). Patient information materials in general practices and promotion of health literacy: an observational study of their effectiveness. *British Journal of General Practice, 65*(632), e192-e197.

Public Health England. (2014). NHS Health Check programme standards: a framework for quality improvement. London, UK.

Public Health England. (2015a). 3.8 million people in England now have diabetes [Press release]. Retrieved from https://www.gov.uk/government/news/38-million-people-in-england-now-have-diabetes

Public Health England. (2015b). Diabetes prevalence estimates for local populations. UK: Crown

Public Health England. (2016a). Eatwell Guide. UK: Crown.

Public Health England. (2016b). *Health matters: getting every adult active every day*. Crown. Retrieved from https://www.gov.uk/government/publications/health-matters-getting-every-adult-active-every-day/health-matters-getting-every-adult-active-every-day.

Public Health England. (2018). One You. Retrieved June 2018, from https://www.nhs.uk/oneyou/

Public Health Service. (1979). Healthy People: the Surgeon General's report on health promotion and disease prevention. Washington, DC: US Department of Health, Education, and Welfare.

Ragir, S. (2000). Diet and food preparation: Rethinking early hominid behavior. *Evolutionary Anthropology 9*(4), 153-155.

Reeve, J., Jang, H., Hardre, P. & Omura, M. (2002). Providing a Rationale in an Autonomy-Supportive Way as a Strategy to Motivate Others During an Uninteresting Activity. *Motivation and Emotion, 26*(3), 183-207.

Rendel, J. M. (1970). The time scale of genetic change. In S. V. Boyden (Ed.), *The impact of civilization on the biology of man* (pp. 27-47). Canberra, Australia: Australian National University Press.

Resnick, B. (2001). Testing a Model of Overall Activity in Older Adults. *Journal of Aging & Physical Activity, 9*(2), 142.

Resnick, B., Zimmerman, S., Orwig, D., Furstenberg, A. & Magaziner, J. (2001). Model Testing for Reliability and Validity of the Outcome Expectations for Exercise Scale. *Nursing Research, 50*(5), 293-299.

Revedin, A., Aranguren, B., Becattini, R., Longo, L., Marconi, E., Lippi, M. M., . . . Svoboda, J. (2010). Thirty thousand-year-old evidence of plant food processing. *Proceedings of the National Academy of Sciences of the United States of America, 107*(44), 18815-18819.

Ritchie, J., Lewis, J., Elam, G., Tennant, R. & Rahim, N. (2014). Designing and selecting samples. In J. Ritchie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative Research Practice* (Second ed.). London, UK: Sage.

Ritchie, J. & Ormston, R. (2014). The applications of qualitative methods to social research. In J. Ritchie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative Research Practice* (pp. 27-46). London, UK: Sage.

Roach, N. T., Venkadesan, M., Rainbow, M. J. & Lieberman, D. E. (2013). Elastic energy storage in the shoulder and the evolution of high-speed throwing in Homo. *Nature, 498*(7455), 483-486.

Roberts, K. & Marvin, K. (2011). Knowledge and attitudes towards healthy eating and physical activity: what the data tell us. Oxford, UK: National Obesity Observatory.

Robertson, C., Archibald, D., Avenell, A., Douglas, F., Hoddinott, P., van Teijlingen, E., . . . Fowler, C. (2014). Systematic reviews of and integrated report on the quantitative, qualitative and economic evidence base for the management of obesity in men. *Health Technology Assessment, 18*(35).

Robertson, R. (2008). Using Information to Promote Healthy Behaviours. *Kicking Bad Habits*. London, UK: The King's Fund.

Rodham, K. (2018). Overrated: self-management. *The Psychologist, 31*, 34-37.

Roesch, S., Norman, G. J., Villodas, F., Sallis, J. F. & Patrick, K. (2010). Intervention-mediated effects for adult physical activity: A latent growth curve analysis. *Social of Science & Medicine, 71*(3), 494-501.

Rogers, A. M. M., Lemmen, K., Kramer, R., Mann, J. & Chopra, V. (2017). Internet-Delivered Health Interventions That Work: Systematic Review of Meta-Analyses and Evaluation of Website Availability. *Journal of Medical Internet Research, 19*(3), e90.

Rolian, C., Lieberman, D. E. & Zermeno, J. P. (2011). Hand biomechanics during simulated stone tool use. *Journal of Human Evolution, 61*(1), 26-41.

Rollnick, S., Butler, C. C., McCambridge, J., Kinnersley, P., Elwyn, G. & Resnicow, K. (2005). Consultations about changing behaviour. *BMJ, 331*(7522), 961-963.

Rolls, E. T. (2012). Taste, olfactory and food texture reward processing in the brain and the control of appetite. *Proceedings of the Nutrition Society, 71*(04), 488-501.

Ruff, C. B. (2000). Body mass prediction from skeletal frame size in elite athletes. *American Journal of Physical Anthropology, 113*(4), 507-517.

Rutten, G., Meis, J., Hendriks, M., Hamers, F., Veenhof, C. & Kremers, S. (2014). The contribution of lifestyle coaching of overweight patients in primary care to more autonomous motivation for physical activity and healthy dietary behaviour: results of a longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 86.

Ryan, R. M. & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78.

Ryan, R. M. & Deci, E. L. (2006). Self-Regulation and the Problem of Human Autonomy: Does Psychology Need Choice, Self-Determination, and Will? *Journal of Personality, 74*(6), 1557-1586.

Ryberg, M., Sandberg, S., Mellberg, C., Stegle, O., Lindahl, B., Larsson, C., . . . Olsson, T. (2013). A Palaeolithic-type diet causes strong tissue-specific effects on ectopic fat deposition in obese postmenopausal women. *Journal of Internal Medicine, 274*(1), 67-76.

Sadoski, M. (2001). Resolving the effects of concreteness on interest, comprehension, and learning important ideas from text. *Educational Psychology Review, 13*(3), 263-281.

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K. & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health, 27*(1), 297-322.

Sallis, J. F., Owen, N. & Fisher, E. B. (2008). Ecological models of health behavior *Health behavior and health education: Theory, research, and practice* (4th ed., pp. 465-485). San Francisco, California: Jossey-Bass.

Santos, I., Silva, M. N. & Teixeira, P. J. (2016). A self-determination theory perspective on weight loss maintenance. *The European Health Psychologist, 18*(5), 194-199.

Savard, A., Joussemet, M., Pelletier, J. E. & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37*(4), 688-700.

Scarborough, P., Bhatnagar, P., Wickramasinghe, K. K., Allender, S., Foster, C. & Rayner, M. (2011). The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006–07 NHS costs. *Journal of Public Health*.

Scheers, T., Philippaerts, R. & Lefevre, J. (2012). Variability in physical activity patterns as measured by the SenseWear Armband: how many days are needed? *European Journal of Applied Physiology, 112*(5), 1653-1662.

Scheltema, E., Reay, S. & Piper, G. (2018). Visual representation of medical information: the importance of considering the end-user in the design of medical illustrations. *Journal of Visual Communication in Medicine, 41*(1), 9-17.

Schofield, W. N. (1985). Predicting basal metabolic rate, new standards and review of previous work. *Clinical Nutrition, 39*(S1), 5-41.

Schulkin, J. (1991). The allure of salt. *Psychobiology, 19*(2), 116-121.

Schulz, L. O., Bennett, P. H., Ravussin, E., Kidd, J. R., Kidd, K. K., Esparza, J. & Valencia, M. E. (2006). Effects of traditional and western environments on prevalence of type 2 diabetes in Pima Indians in Mexico and the U.S. *Diabetes Care, 29*(8), 1866-1871.

Schwartz, M. W., Woods, S. C., Porte, D., Seeley, R. J. & Baskin, D. G. (2000). Central nervous system control of food intake. *Nature, 404*(6778), 661-671.

Schwarzer, R. (2008). Modeling Health Behavior Change: How to Predict and Modify the Adoption and Maintenance of Health Behaviors. *Applied Psychology, 57*(1), 1-29.

Scott, J. (2014a). Re-evolution of Thought. Retrieved from http://re-evolutionary.com/2014/12/23/reevolution-of-thought/

Scott, J. (2014b, 8th August). *The Underappreciated Role of Muscle in Health and Disease.* Paper presented at the Ancestral Health Symposium Berkeley, CA.

Scott, N. W., McPherson, G. C., Ramsay, C. R. & Campbell, M. K. (2002). The method of minimization for allocation to clinical trials: a review. *Controlled Clinical Trials, 23*(6), 662-674.

Sebire, S. J., Standage, M. & Vansteenkiste, M. (2008). Development and Validation of the Goal Content for Exercise Questionnaire. *Journal of Sport & Exercise Psychology, 30*(4), 353-377.

Sekhon, M., Cartwright, M. & Francis, J. J. (2017). Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. *BMC Health Services Research, 17*(1), 88.

Shakespeare, T. P., Gebski, V. J., Veness, M. J. & Simes, J. (2001). Improving interpretation of clinical studies by use of confidence levels, clinical significance curves, and risk-benefit contours. *The Lancet, 357*(9265), 1349-1353.

Shen, F., Sheer, V. & Li, R. (2015). Impact of Narratives on Persuasion in Health Communication: A Meta-Analysis. *Journal of Advertising, 44*(2), 105 - 113.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22*(2), 63-75.

Shephard, R. J. & Rhode, A. (1996). *The health consequences of "modernization‟. Evidence from circumpolar peoples*. Cambridge, UK: Cambridge University Press.

Short, C., Rebar, A., Plotnikoff, R. C. & Vandelanotte, C. (2015). Designing engaging online behaviour change interventions: A proposed model of user engagement. *The European Health Psychologist, 17*(1), 32-38.

Silva, M., Vieira, P., Coutinho, S., Minderico, C., Matos, M., Sardinha, L. & Teixeira, P. (2010). Using self-determination theory to promote physical activity and weight control: a randomized controlled trial in women. *Journal of Behavioral Medicine, 33*(2), 110-122.

Silvia, P. J. (2005). What Is Interesting? Exploring the Appraisal Structure of Interest. *Emotion, 5*(1), 89-102.
Silvia, P. J. (2006). *Exploring the psychology of interest*. Oxford: Oxford University Press.
Silvia, P. J. (2008). Interest—The Curious Emotion. *Current Directions in Psychological Science, 17*(1), 57-60.
Silvia, P. J. (2010). Confusion and interest: The role of knowledge emotions in aesthetic experience. *Psychology of Aesthetics, Creativity, and the Arts, 4*(2), 75-80.
Silvia, P. J., Henson, R. A. & Templin, J. L. (2009). Are the sources of interest the same for everyone? Using multilevel mixture models to explore individual differences in appraisal structures. *Cognition and Emotion, 23*(7), 1389-1406.
Singal, A. G., Higgins, P. D. R. & Waljee, A. K. (2014). A Primer on Effectiveness and Efficacy Trials. *Clinical and Translational Gastroenterology, 5*, e45.
Slater, M. D. & Rouner, D. (2002). Entertainment—Education and Elaboration Likelihood: Understanding the Processing of Narrative Persuasion. *Communication Theory, 12*(2), 173-191.
Slimani, N., Deharveng, G., Southgate, D. A., Biessy, C., Chajes, V., van Bakel, M. M., . . . Bingham, S. (2009). Contribution of highly industrially processed foods to the nutrient intakes and patterns of middle-aged populations in the European Prospective Investigation into Cancer and Nutrition study. *European Journal of Clinical Nutrition, 63 Suppl 4*, S206-225.
Smith, J. A. (2008). *Qualitative psychology: a practical guide to research methods* (2ND ed.). London, UK: SAGE.
Smith, L. P., Ng, S. W. & Popkin, B. M. (2014). No time for the gym? Housework and other non-labor market time use patterns are associated with meeting physical activity recommendations among adults in full-time, sedentary jobs. *Social Science & Medicine, 120*(0), 126-134.
Smithsonian Institution. (2014a). Climate Effects on Human Evolution. Retrieved November 26, 2014, from http://humanorigins.si.edu/research/climate-research/effects
Smithsonian Institution. (2014b). Human evolution timeline interactive. Retrieved November 26, 2014, from http://humanorigins.si.edu/evidence/human-evolution-timeline-interactive
Smithsonian Institution. (2014c). Human skin color diversity. Retrieved December 6, 2014, from http://humanorigins.si.edu/evidence/genetics/skin-color/modern-human-diversity-skin-color
Smithsonian Institution. (2014d). Introduction to Human Evolution. Retrieved November 25, 2014, from http://humanorigins.si.edu/resources/intro-human-evolution
Smithsonian Institution. (2014e). New Tools, New Foods. Retrieved November 26, 2014, from http://humanorigins.si.edu/human-characteristics/tools-food
Smithsonian Institution. (2015a). Human Characteristics: Brains. Retrieved May 23, 2015, from http://humanorigins.si.edu/human-characteristics/brains
Smithsonian Institution. (2015b). Social Life. Retrieved May 23, 2015, from http://humanorigins.si.edu/human-characteristics/social
Sniehotta, F. F., Presseau, J. & Araújo-Soares, V. (2014). Time to retire the theory of planned behaviour. *Health Psychology Review, 8*(1), 1-7.
Sniehotta, F. F., Scholz, U. & Schwarzer, R. (2005). Bridging the intention–behaviour gap: Planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. *Psychology & Health, 20*(2), 143-160.
Sniehotta, F. F., Schwarzer, R., Scholz, U. & Schüz, B. (2005). Action planning and coping planning for long-term lifestyle change: theory and assessment. *European Journal of Social Psychology, 35*(4), 565-576.

Sniehotta, F. F., Simpson, S. A. & Greaves, C. J. (2014). Weight loss maintenance: An agenda for health psychology. *British Journal of Health Psychology, 19*(3), 459-464.

Song, H. & Schwarz, N. (2010). If it's easy to read, it's easy to do, pretty, good, and true. *The Psychologist, 23*, 108 - 111.

Speakman, J. R. (2007). A Nonadaptive Scenario Explaining the Genetic Predisposition to Obesity: The “Predation Release” Hypothesis. *Cell Metabolism, 6*(1), 5-12.

Speakman, J. R. (2008). Thrifty genes for obesity, an attractive but flawed idea, and an alternative perspective: the 'drifty gene' hypothesis. *International Journal of Obesity, 32*(11), 1611-1617.

Spencer, L., Ritchie, J., O'Connor, W., Morrell, G. & Ormston, R. (2014). Analysis in Practice. In J. Ritchie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative Research Practice: A Guide for Social Science Students and Researchers* (pp. 295-346). London: Sage.

Spencer, L., Ritchie, J., Ormston, R., O'Connor, W. & Barnard, M. (2014). Analysis: Principles and Processes. In J. Ritchie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative Research Practice: A Guide for Social Science Students and Researchers* (pp. 269-294). London: Sage.

Spiteri Cornish, L. & Moraes, C. (2015). The Impact of Consumer Confusion on Nutrition Literacy and Subsequent Dietary Behavior. *Psychology & Marketing, 32*(5), 558-574.

Spring, B., Moller, A. C. & Coons, M. J. (2012). Multiple health behaviours: overview and implications. *Journal of Public Health, 34*(S1), i3-i10.

Standage, M., Duda, J. L. & Ntoumanis, N. (2005). A test of self-determination theory in school physical education. *British Journal of Educational Psychology, 75*(3), 411-433.

Stevens, G., Singh, G., Lu, Y., Danaei, G., Lin, J., Finucane, M., . . . Ezzati, M. (2012). National, regional, and global trends in adult overweight and obesity prevalences. *Population Health Metrics, 10*(1), 22.

Stokols, D. (1996). Translating Social Ecological Theory into Guidelines for Community Health Promotion. *American Journal of Health Promotion, 10*(4), 282-298.

Sun, J. C.-Y. & Rueda, R. (2012). Situational interest, computer self-efficacy and self-regulation: Their impact on student engagement in distance education. *British Journal of Educational Technology, 43*(2), 191-204.

Susman, R. L. (1998). Hand function and tool behavior in early hominids. *Journal of Human Evolution, 35*(1), 23-46.

Tang, J., Abraham, C., Stamp, E. & Greaves, C. (2015). How can weight-loss app designers' best engage and support users? A qualitative investigation. *British Journal of Health Psychology, 20*(1), 151-171.

Tang, J. C. H., Abraham, C., Greaves, C. J. & Nikolaou, V. (2016). Self-directed interventions to promote weight loss: a systematic review and meta-analysis. *Health Psychology Review*, 1-15.

Taves, D. R. (1974). Minimization: A new method of assigning patients to treatment and control groups. *Clinical Pharmacology & Therapeutics, 15*(5), 443 - 453.

Taylor-Davis, S., Smiciklas-Wright, H., Warland, R. E. X., Achterberg, C., Jensen, G., Sayer, A. & Shannon, B. (2000). Responses of Older Adults to Theory-Based Nutrition Newsletters. *Journal of the American Dietetic Association, 100*(6), 656-664.

Taylor, N., Conner, M. & Lawton, R. (2012). The impact of theory on the effectiveness of worksite physical activity interventions: a meta-analysis and meta-regression. *Health Psychology Review, 6*(1), 33-73.

Teixeira, P. J., Carraça, E. V., Marques, M. M., Rutter, H., Oppert, J.-M., De Bourdeaudhuij, I., . . . Brug, J. (2015). Successful behavior change in obesity interventions in adults: a systematic review of self-regulation mediators. *BMC Medicine, 13*(1), 84.

Teixeira, P. J., Patrick, H. & Mata, J. (2011). Why we eat what we eat: the role of autonomous motivation in eating behaviour regulation. *Nutrition Bulletin, 36*(1), 102-107.

The Ancestral Health Society. (2014). About the Ancestral Health Society. Retrieved January, 2015, from http://www.ancestralhealth.org/about

The King's Fund. (2013). Non-communicable diseases. Retrieved April 26th, 2015, from http://www.kingsfund.org.uk/time-to-think-differently/trends/disease-and-disability/non-communicable-diseases

Thoman, D. B., Smith, J. L. & Silvia, P. J. (2011). The Resource Replenishment Function of Interest. *Social Psychological and Personality Science, 2*(6), 592-599.

Thompson, D. (2013). Physical activity for physiologists. *Physiology News, 92*, 4.

Thompson, D., Batterham, A. M., Markovitch, D., Dixon, N. C., Lund, A. J. & Walhin, J. P. (2009). Confusion and conflict in assessing the physical activity status of middle-aged men. *PLoS One, 4*(2), e4337.

Thompson, T. & Kreuter, M. W. (2014). Using Written Narratives in Public Health Practice: A Creative Writing Perspective. *Preventing Chronic Disease, 11*, 1-7.

Tocheri, M. W., Orr, C. M., Jacofsky, M. C. & Marzke, M. W. (2008). The evolutionary history of the hominin hand since the last common ancestor of Pan and Homo. *Journal of Anatomy, 212*(4), 544-562.

Tones, K. & Tilford, S. (2001). *Health Promotion: Effectiveness, Efficiency and Equity*. Cheltenham, UK: Nelson Thornes.

Treasure, T. & MacRae, K. D. (1998). Minimisation: the platinum standard for trials? *British Medical Journal, 317*(7155), 362-363.

Trevathan, W. R. (2007). Evolutionary Medicine. *Annual Review of Anthropology, 36*(1), 139-154.

Truswell, A. S. & Hansen, J. D. L. (1976). Medical research among the !Kung. In R. B. Lee & I. De Vore (Eds.), *Kalahari hunter-gatherers* (pp. 166-194). Cambridge, MA: Harvard University Press.

Turner, B. L. & Thompson, A. L. (2013). Beyond the Paleolithic prescription: incorporating diversity and flexibility in the study of human diet evolution. *Nutrition Reviews, 71*(8), 501-510.

U.S. News and World Report. (2015). Best Diets. Retrieved May, 2015, from http://health.usnews.com/best-diet

Vähäsarja, K., Kasila, K., Kettunen, T., Rintala, P., Salmela, S. & Poskiparta, M. (2015). 'I saw what the future direction would be…': Experiences of diabetes risk and physical activity after diabetes screening. *British Journal of Health Psychology, 20*(1), 172-193.

van Jaarsveld, C. H. M. & Gulliford, M. C. (2015). Childhood obesity trends from primary care electronic health records in England between 1994 and 2013: population-based cohort study. *Archives of Disease in Childhood, 100*(3), 214-219.

van Reenen, M. & Oppe, M. (2015). EQ-5D-3L User Guide. Rotterdam, The Netherlands: EuroQol Group.

Vandelanotte, C. (2013). Are Simultaneously Delivered Health Behavior Change Interventions the Way of the Future?: a Comment on King et al. *Annals of Behavioral Medicine, 46*(2), 133-134.

Vandelanotte, C., Müller, A. M., Short, C. E., Hingle, M., Nathan, N., Williams, S. L., . . . Maher, C. A. (2016). Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. *Journal of Nutrition Education and Behavior, 48*(3), 219-228.e211.

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E. & Reeve, J. (2018). Fostering Personal Meaning and Self-relevance: A Self-Determination Theory Perspective on Internalization. *The Journal of Experimental Education, 86*(1), 30-49.

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B. & Matos, L. (2005). Examining the Motivational Impact of Intrinsic Versus Extrinsic Goal Framing and Autonomy-Supportive Versus Internally Controlling Communication Style on Early Adolescents' Academic Achievement. *Child Development, 76*(2), 483-501.

Vansteenkiste, M., Simons, J., Soenens, B. & Lens, W. (2004). How to Become a Persevering Exerciser? Providing a Clear, Future Intrinsic Goal in an Autonomy-Supportive Way. *Journal of Sport and Exercise Psychology, 26*(2), 232-249.

Vansteenkiste, M., Williams, G. C. & Resnicow, K. (2012). Toward systematic integration between self-determination theory and motivational interviewing as examples of top-down and bottom-up intervention development: autonomy or volition as a fundamental theoretical principle. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 23.

Warinner, C. (2013). Debunking the paleo diet. Retrieved October, 2014, from http://tedxtalks.ted.com/video/Debunking-the-Paleo-Diet-Christ

Waters, L., Reeves, M., Fjeldsoe, B. & Eakin, E. (2012). Control Group Improvements in Physical Activity Intervention Trials and Possible Explanatory Factors: A Systematic Review. *Journal of Physical Activity and Health, 9*(6), 884-895.

Webb, T. L., Joseph, J., Yardley, L. & Michie, S. (2010). Using the Internet to Promote Health Behavior Change: A Systematic Review and Meta-analysis of the Impact of Theoretical Basis, Use of Behavior Change Techniques, and Mode of Delivery on Efficacy. *Journal of Medical Internet Research, 12*(1), e4.

Webb, T. L. & Sheeran, P. (2006). Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin, 132*(2), 249-268.

Weininger, J. (2015). Human nutrition. Encyclopaedia Britannica. Retrieved from http://www.britannica.com/EBchecked/topic/422896/human-nutrition/250633/Body-mass-body-fat-and-body-water.

Welk, G. J., McClain, J. J., Eisenmann, J. C. & Wickel, E. E. (2007). Field Validation of the MTI Actigraph and BodyMedia Armband Monitor Using the IDEEA Monitor. *Obesity, 15*(4), 918-928.

Western, M. J. (2017). *Using personalised multidimensional visual feedback to support a change in physical activity behaviour and improve health.* (Doctoral thesis), University of Bath.

Williams, B. & Cameron, L. (2009). Images in health care: potential and problems. *Journal of Health Services Research & Policy, 14*(4), 251-254.

Williams, G. C., Lynch, M. & Glasgow, R. E. (2007). Computer-assisted intervention improves patient-centered diabetes care by increasing autonomy support. *Health Psychology, 26*(6), 728-734.

Williams, G. C., Niemiec, C. P., Patrick, H., Ryan, R. M. & Deci, E. L. (2009). The importance of supporting autonomy and perceived competence in facilitating long-term tobacco abstinence. *Annals of Behavioral Medicine, 37*(3), 315-330.

Wilson, B. J. (2007). Designing Media Messages About Health and Nutrition: What Strategies Are Most Effective? *Journal of Nutrition Education and Behavior, 39*(2, Supplement), S13-S19.

Wilson, P. M., Rodgers, W. M., Loitz, C. C. & Scime, G. (2006). “It's Who I Am … Really!’ The Importance of Integrated Regulation in Exercise Contexts. *Journal of Applied Biobehavioral Research, 11*(2), 79-104.

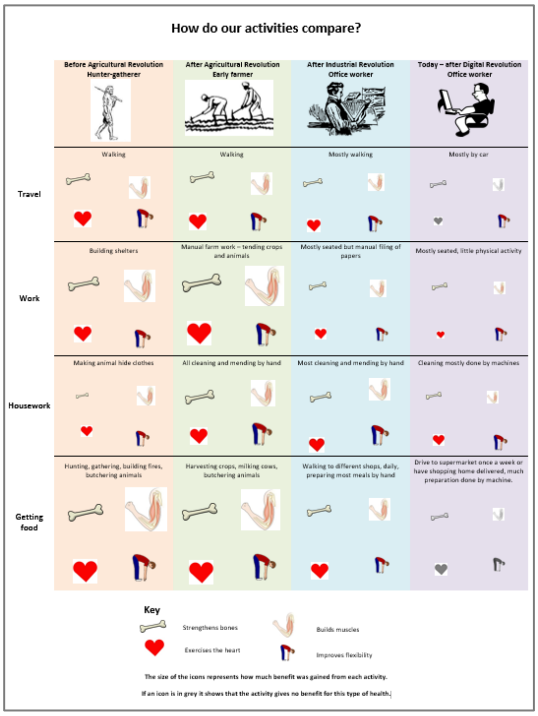
Wing, R. R., Lang, W., Wadden, T. A., Safford, M., Knowler, W. C., Bertoni, A. G., . . . The Look Ahead Research Group. (2011). Benefits of Modest Weight Loss in Improving Cardiovascular Risk Factors in Overweight and Obese Individuals With Type 2 Diabetes. *Diabetes Care, 34*(7), 1481-1486.

Winston, R. (2002). *Human Instinct*. London, UK: Bantam Books.
Wolfe, R. R. (2006). The underappreciated role of muscle in health and disease. *The American Journal of Clinical Nutrition, 84*(3), 475-482.
Wong, G. W. K. & Wright, J. M. (2014). Blood pressure lowering efficacy of nonselective beta-blockers for primary hypertension. *Cochrane Database of Systematic Reviews*(2).
World Health Organization. (2007). Protein and amino acid requirements in human nutrition.Report of a joint WHO/FAO/UNU expert consultation. Geneva, Switzerland: World Health Organization.
World Health Organization. (2008). Waist circumference and waist–hip ratio: Report of a WHO expert consultation, Geneva, 8-11 December
World Health Organization. (2015). Body Mass Index - BMI. Retrieved July, 2015, from http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi
Wright, P. (2012). Using Graphics Effectively in Text. In C. Abraham & M. Kools (Eds.), *Writing Health Communication: An Evidence-based Guide*. London, UK: SAGE Publications Ltd.
Yajnik, C. S. (2004). Early Life Origins of Insulin Resistance and Type 2 Diabetes in India and Other Asian Countries. *The Journal of Nutrition, 134*(1), 205-210.
Yeo, A., Legard, R., Keegan, J., Ward, K., McNaughton Nicholls, C. & Lewis, J. (2014). In-depth interviews. In J. Ritchie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative Research Practice* (Second ed.). London, UK: Sage.
Zuk, M. (2013). *Paleofantasy: What Evolution Really Tells us About Sex, Diet, and How We Live*. London, UK: W. W. Norton & Company Ltd.

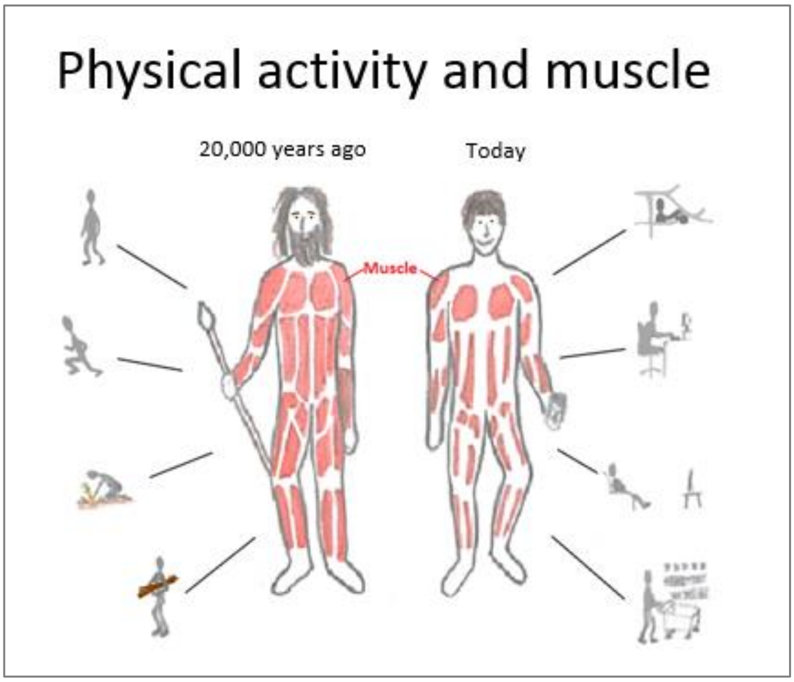
Appendices

Appendix 3.1 Graphics to illustrate specific physical activity and diet concepts (Study 1)

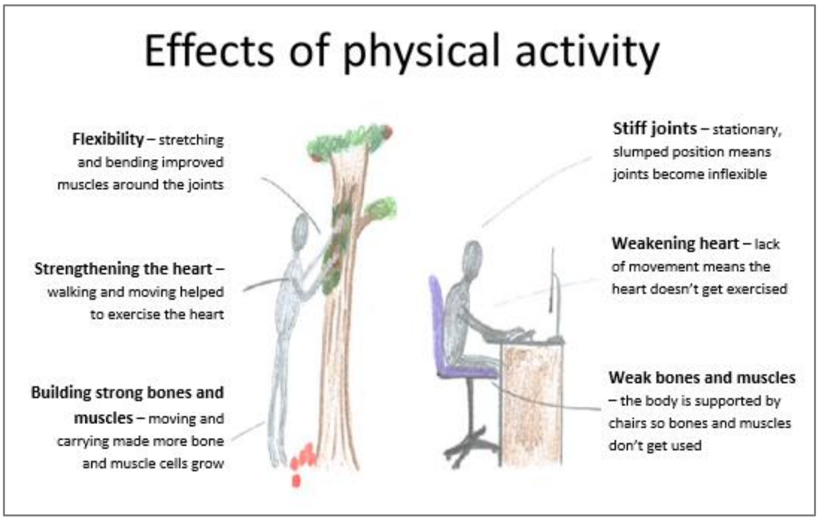
3.1a Physical activity comparison table



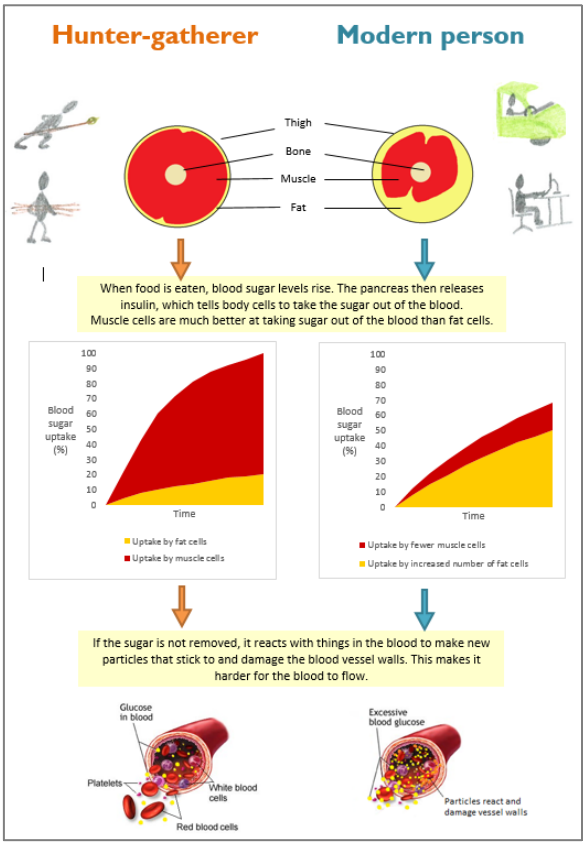
3.1b Muscle comparison



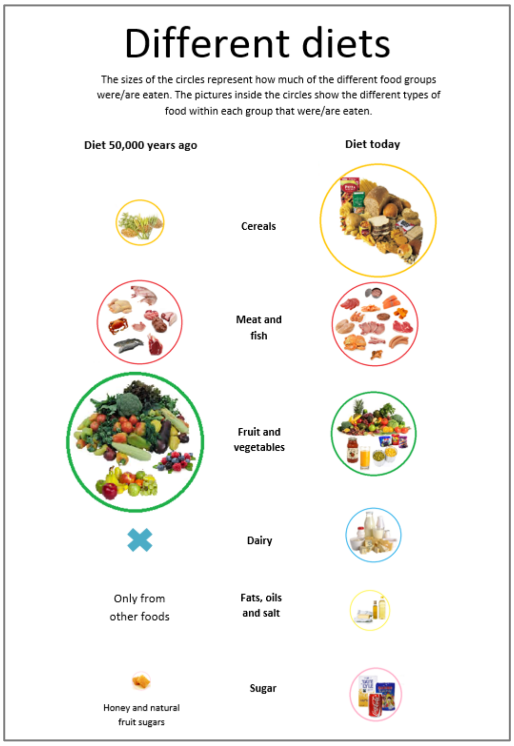
3.1c Physical activity comparison



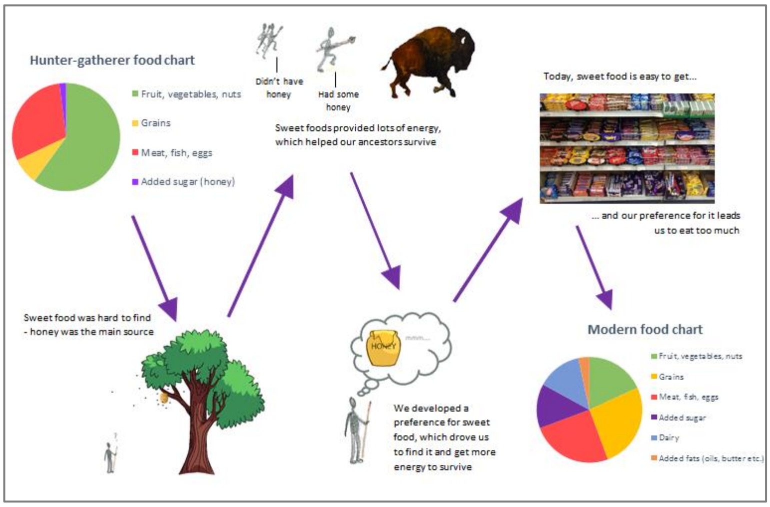
3.1d Muscle and sugar infographic



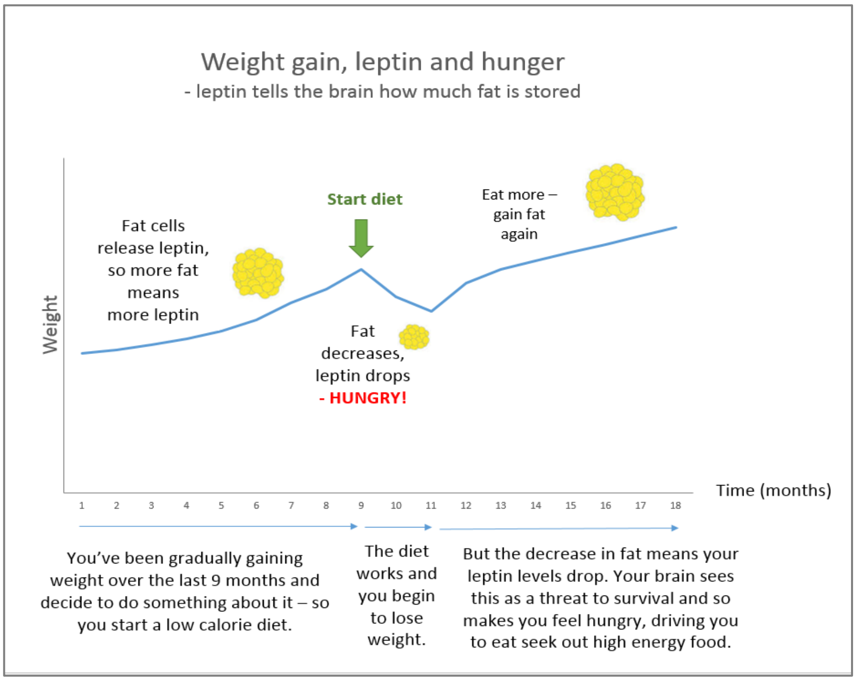
3.1e Food type circles



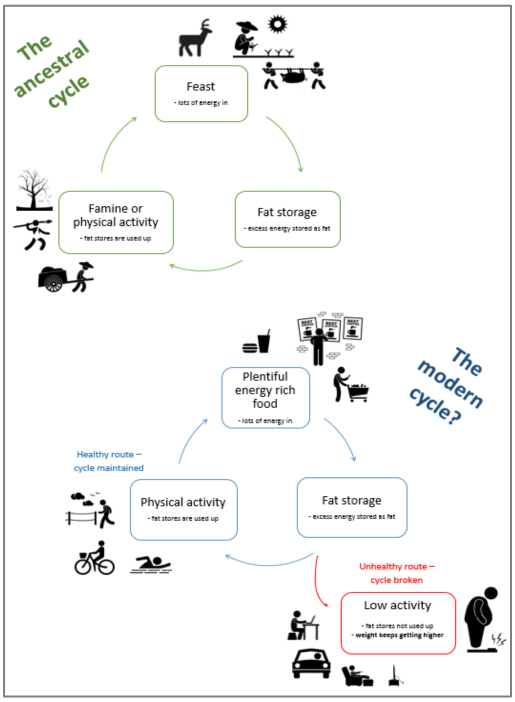
3.1f Sugar preference storyboard



3.1g Leptin and weight-loss graph



3.1h Fat cycles



Appendix 3.2 Introductory mismatch concept text (Study 1)

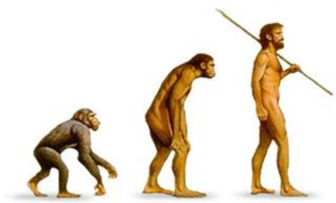
Can your body cope with modern life?

The things we do in the course of our lives can have huge effects on our bodies – smoking, for instance, is well known to damage the lungs, heart and blood vessels. But our ancestors' lives have also affected our bodies and learning about how they lived can help us to understand why humans are the way they are in the first place. Knowing this can help us to see why some diseases occur and to understand what things we need to do to help prevent us getting ill.

The changing human body

Genes are instructions for the body; they tell the body how to develop, affecting many aspects of our lives, from what we look like to how our bodies function.

The human body has been shaped over millions of years of evolution. Along the way our ancestors have lived in many different environments: facing ice ages and tropical heat waves, and eating a huge variety of foods depending on what was available. When the environment changed - for example through climate warming or cooling, humans travelling to new areas or when humans changed their own environment - **the process of evolution gradually adapted the human body to better suit the new environment**. People with **genes** that made their bodies better able to survive and reproduce would pass their genes on to their children, the next generation, making them in turn more likely to survive and reproduce.



With each new generation of humans, adaptive genes will be spread a bit further, but **it usually takes several hundred generations (and thus thousands of years) for adaptive genes to spread throughout a whole population.** For example, early humans were poorly adapted for walking on two legs as their spines and hips were still very 'ape-like'. Fossil records show how the human body gradually gained an s-shaped spine and large hips, which make us steadier on two feet. But this has taken over 6 million years! Evolution isn't always *that* slow – humans only started to drink milk from other animals less than 10,000 years ago and at first very few adults were able to digest it. Now, a third of the world's population have the genes that allow their bodies to digest cows' milk. But this has still taken several hundred generations to adapt to one small change in our environment.

So, changes in the environment help to shape the human body but changes to the body take a long time to occur. This means that:

- We will be better adapted to things that have stayed relatively unchanged in our environment, because the human body will have had longer to adapt to them

- We are unlikely to be well adapted to changes in the environment that didn't last very long or that have occurred recently, because the human body won't have had time to adapt.

The changing environment

What do we mean by 'environment'? We aren't just talking about the countryside but all the conditions that surround us – these can be physical things like people, buildings and technology as well as things that can't be seen.

Changes in the **environment** help to shape the human body, so it is useful to look at how our environment has changed over the years and see what has had the biggest impact on human lifestyles.

The very first humans separated from the ape family about 6 million years ago and many different species of human have existed since then. Modern humans (Homo *sapiens*) are the only surviving species and evolved from their ancestors about 200,000 years ago. For most of humans' 6 million year history our ancestors survived by hunting, scavenging and gathering foods and lived in small groups that moved about the land.

About 12,000 years ago though, some humans started to grow plants from seeds they collected – they could then eat the plants that they grew. This was the start of farming, also known as the **Agricultural Revolution**. People came to depend more on the plants they grew and less on hunting and gathering for food. They also started to tame wild animals and were able to breed them for food. Farming gradually spread around the world and became the normal way of life for most of the population – it greatly affected the foods we ate and their daily activities.

The next big change to humans' environment was the **Industrial Revolution**, which happened much more recently – about 250 years ago. The Industrial Revolution saw machines take over the work of humans. Machines were often able to do the work of several humans, much faster and in larger quantities. As more machines were invented they quickly became an everyday part of human lives – affecting everything from the ways we travelled to the foods we ate and how we communicated with each other.

The Industrial Revolution kick-started a great many changes to our environment and these have occurred in a relatively short time (when thinking about other changes in human history). Since computers were invented, about 60 years ago, the pace of change has become even faster, with many tasks now being completely controlled by computers without the need for humans to lift a finger. Indeed, some people are calling our age the **Digital Revolution**.

What these changes mean for us today

Although humans have lived in many different environments throughout our history, 2 important things stayed much the same for our ancestors:

- Physical activity was essential for everyday life
- Energy-rich foods were scarce

Our lifestyles have evolved too quickly for our genes to keep up → our bodies are struggling to cope

But recently our environment has changed a lot, and now these 2 things have completely reversed. Today it is possible to work and get food without moving much at all and energy-rich foods are widely available. **The changes to our environment have happened too quickly for bodies to adapt and this leads to us getting ill**. Conditions such as type 2 diabetes and cardiovascular diseases (e.g. high blood pressure, heart disease) can develop as our bodies struggle to cope with our lower levels of activity and larger amounts of calorie rich foods.

Coping with change

We don't want to change our environment back to what it was thousands or even hundreds of years ago - and we probably wouldn't be able to anyway. Many modern advances have been good for our health (and they certainly make things easier for us!) For example, we can quickly access safe, clean drinking water and immunisations have greatly lowered the spread of deadly diseases like measles. But we can make a few simple changes to our lifestyles – **making our diets and physical activity levels slightly more like those of our ancestors** – that will help make us healthier while still getting all the benefits of modern technology.

Appendix 3.3 Physical activity text (Study 1)

Machines can lead an active life, so we don't have to…

For most of human history physical activity (movement) was essential for getting food and therefore surviving. Early humans had to hunt and kill animals or gather plants to eat. This involved walking or running, stretching and bending (to pick fruits and vegetables), and carrying what they found back to their group. Because foods did not keep well (there were no fridges!) these activities took place every day or every other day. All food was prepared by hand – including butchering an animal, which required a lot of strength. Materials for building fires and shelters also had to be collected. Stone tools helped them with these tasks, but making the tools also needed a lot of strength.

After the Agricultural Revolution our ancestors had to work hard to look after their crops and animals. Before machinery was invented all farming had to be done by hand – preparing the ground, sowing seeds, weeding, protecting crops, harvesting, processing food and milking animals. Early farmers worked long days, every day of the year. People often had to be skilled in many different tasks – growing plants, looking after animals, mending and making things. So although farming meant our ancestors could eat more, they also had to be more active.

The Industrial Revolution started a huge change in the amount of activity humans do in their everyday lives. As machines took over much of the physical labour involved in most jobs, humans were able to specialise in non-physical tasks – the 'office job' was born. But it wasn't until the Digital Revolution made labour-saving technology cheap and easily available that physical activity became almost entirely an 'optional extra'. Our environment has now changed so much that physical activity is something we only do if we *want* to rather than because we *have* to for work or housekeeping.

Going back just 60 years, before the Digital Revolution, physical activity was still necessary for daily life:

- Only 10% of families had a car - people walked a lot more, for example to get to shops.
- Only 33% of households had a washing machine – most people washed their clothes by hand.
- Only 15% of households had a fridge – people had to go to the shops more often because food did not keep for very long.

Why do we need to be active?

Because physical activity has been such a necessary part of life for most of our ancestors, the human body has adapted to make use of physical activity – **being active makes the body function better**.

Although physical activity is often thought of as something to do if you want to lose weight or not get fat, it **isn't just good for burning calories**. Here are 4 important good effects that being active has on the body:

1. ***Building strong bones*** - in order to cope with physical activity our bodies make more bone cells. This is important as stronger, denser bones are less likely to break.

2. ***Improving flexibility*** – physical activity improves our flexibility by strengthening and lengthening the muscles around our joints. This helps us to move more easily and prevents injury.

3. ***Strengthening the heart*** – the heart is also made of muscle (cardiac muscle) and during physical activity this muscle has to work harder to pump blood around the body at a faster rate. In response to the extra work more cells develop to make the heart better able to cope. This helps to prevent heart disease.

4. ***Building strong muscles*** – physical activity causes the body to make more and bigger muscle cells. This is important because muscle cells are very good at taking sugar out of the blood, which prevents dangerously high blood sugar levels after a meal (one of the signs of type 2 diabetes). Strong muscles also improve our balance and reaction times, which helps prevent

So, **activity is important for everyone**, not just people who want to shed a few pounds (although it does help with that too!)

Goodbye muscles … hello sticky blood cells!

Muscle tissue is very good at taking sugar out of the blood. This process is controlled by a hormone called insulin, which tells the body's cells to remove sugar from blood – the cells can then use the sugar for energy or store it. Fat tissue is not as good as muscle tissue at taking sugar from the blood, it needs a lot more insulin than muscle cells in order to take up the same amount of sugar.

If the sugar is not removed, it joins with things in the blood to make new particles that stick to and damage the blood vessel walls. This can make it harder for the blood to flow, increasing blood pressure. The tiny vessels in the eyes and kidneys are particularly affected by this and if blood sugar levels remain high over a long period of time, blindness and kidney failure can occur.

Throughout history, humans have had lots of muscle relative to fat tissue in their bodies. We have evolved to be able to make enough insulin (in our pancreas) for a fairly muscular body. However, in today's environment it is easy to lead very inactive lives leading to low amounts of muscle tissue in our bodies, and relatively higher proportions of fat tissue. This means we need more insulin to take up sugar from the blood quickly enough. **If muscle proportions become too low the body simply cannot produce enough insulin** – when this occurs it is known as type 2 diabetes.

Some fat tissue is essential. Our ancestors needed fat to keep them warm. However, we need a lot more muscle than fat in our bodies. A person may have too much fat relative to muscle tissue because of:

- Too much fat and normal muscle levels (obesity)
- Too little muscle but normal levels of fat (this person may look thin or 'normal' weight)
- Both too little muscle and too much fat (this person may look 'normal', overweight or obese).

Learning from our ancestors

We need to be a bit more active like our ancestors were in order for our bodies to be healthy. But this doesn't mean we need to totally give up technology or spend hours in the gym each week. Some people like to play sport or go to exercise classes and if you think they might work best for your life then get stuck in! But we can also make some everyday tasks a bit more active or try to rely a little less on technology. Here are some simple ideas to get you started:

- **Getting food**

Our hunter-gatherer ancestors walked miles most days to gather food to eat … 60 years ago most people had to walk to and from several different shops to get their groceries …

… Today, we could park our cars in the farthest space of the supermarket car park and carry our bags rather than using the trolley to take them right to the car. We could walk to shops at the weekend when we have a bit more time or use a basket instead of a trolley if we are only getting a few things.

- **Work**

Early farmers had to harvest their crops by hand … the first factory workers had to stand all day long and operate heavy machinery …

… Working in an office, having to use a computer all day, does make it hard to be active but we could try using every opportunity to get out of our seats – for example, going to talk to people in offices within the same building instead of emailing them, making sure we don't just send one person to fetch the teas and coffees, and walking around when making phone calls. If you use a laptop, try putting it on a higher shelf so that you can stand up for a bit during the day.

- **Housework**

Our ancestors had to make, mend and wash their clothes by hand … before vacuum cleaners were invented people had to sweep and beat carpets …

… Actually housework today can give us quite a good 'work out' – we can carry the vacuum cleaner while using it (unless it is an upright model), make sure we really scrub the bath and tiles, and generally put in the 'elbow grease' rather than doing 'a quick wipe round'. Not only will your body benefit but you'll have a lovely clean house too!

Although these little changes might not sound like much on their own, if you make several little changes they will add up to have a significant effect on your health.

Appendix 3.4 Diet text (Study 1)

Is food our friend or foe?

Food is essential for all animals' survival. Because food has been hard to get and not reliably available for most of our ancestors, going right back to the apes, our bodies have evolved many different features to help us get food and use its energy. But our environment has changed a lot and now food is easy to get and reliably available; what's more, the foods that we eat today are often hugely different from what our ancestors ate, even 60 years ago.

This guide will look at the ways in which our bodies' evolved features can lead us to eat more than we should but also struggle to cope with the new types of food we are eating.

Why we evolved a sweet tooth (and a fatty one … and a salty one …)

Naturally sweet and fatty foods tend to be high in calories – they are said to be 'energy-rich' because a relatively small amount of these foods will provide a lot of energy. This was great for our ancestors, who used up a lot of energy just to gather food. So, gathering sweet and fatty foods helped our ancestors to survive better than gathering foods that were less energy-rich. Because of this humans have evolved to prefer sweet and fatty foods – generally we find them more tasty and pleasant to eat. Salty foods were also hard for our ancestors to find. Salt provides an essential mineral (sodium) that our bodies need to function. Therefore humans developed a preference for salty foods - this helped make sure our ancestors got enough sodium.

Old preferences in a new environment

Food and drink companies take advantage of our natural preferences and add sugar or sweeteners, salt and fats to their products to make them highly appealing.

Today, food is readily available all year round and we tend to lead less active lifestyles, so we do not need as much energy as our ancestors. However, our evolved preferences for sweet and fatty foods still remain, prompting us to choose cakes and chips instead of less energy-rich items. Unlike the naturally sweet and fatty foods that our ancestors had, many foods today tend to have been processed or refined in ways that remove vitamins, minerals and fibre. This makes the foods taste sweeter and require less chewing but it also means they only give us energy (calories) and little other goodness. Many foods today also have salt added to them – our preference for salty foods, when they are so easily available, causes us to eat too much of it.

How can our preferences lead to harm?

Here are 4 important risks of eating lots of sugary, fatty and salty foods:

1. **Malnutrition**

The more artificially energy-rich foods we eat, the fewer nutritious foods we eat. This means that while we may get enough or too much energy, we do not get enough nutrients and vitamins, like protein, fibre and vitamin D.

2. **Weight gain**

The energy-rich nature of these foods means a very small portion can contain hundreds of calories – it is easy to consume a lot of calories from them without feeling full. This can lead us to put on weight. Being overweight means your heart has to work harder to pump blood around a larger body. This increases the risk of developing heart disease. It can also raise blood pressure, which weakens the blood vessels.

3. **High blood sugar and diabetes**

Eating foods that contain a large amount of sugar will raise our blood sugar levels a lot. This means that a lot of insulin is needed to tell our bodies to remove the sugar from the blood - our bodies can struggle to produce enough insulin. If our blood sugar levels remain high over a long period (for example, by eating sugary foods every few hours) our blood vessels will be weakened.

4. **High blood pressure**

The kidneys take unnecessary salt out of the blood and get rid of it in our urine. But in order to do this the salt needs to be diluted in the blood with water, so the body holds on to water. This results in a lot of liquid flowing through the blood vessels (the blood plus lots of salt and water molecules) – this increases blood pressure and weakens the vessels.

Learning from our ancestors

It would be impossible to start eating exactly what our hunter-gatherer ancestors did as the animals and plants available to them have evolved as well! It isn't necessary either – our different lifestyles mean that we will need different amounts and types of food. But we can look at the various diets of all our ancestors and see what kinds of foods our bodies are adapted to need and digest. We know that humans need vitamins and minerals, certain fats, protein and fibre, and we have seen that our bodies are not well suited to diets high in sugar, fat and salt. So, we need to reduce our intake of sugary, fatty and salty foods and make sure we get enough of the essential things.

There are lots of little changes we can make to our diets to make them healthier. We can try to ensure that everything we eat contains at least one good thing – vitamins, minerals, protein, fibre or omega 3 fats. Thinking about what kinds of foods were and weren't available to most of our ancestors can help us to make food choices – generally the more natural and less processed or refined a food is, the better it will be.

An example …

It's breakfast time and you want something quick and easy. There's cornflakes, honey nut flakes, porridge, muesli or, of course, wholemeal or white toast. Which would be closer to what was available to our ancestors?

Answer: Porridge or muesli would both be good choices. The oats in porridge and muesli have been processed – to remove the husks and roll the grains – but a lot of the fibre remains intact and no sugar is added (unless you add it yourself!) The other cereals are shaped from highly processed grains, mixed with sugar and salt – the cornflakes would be better than the honey nut flakes though as they will contain less sugar. The bread for the toast is also made from highly processed grains, and many breads have sugar and salt added – wholemeal toast will contain more fibre than white though.



Our funny relationship with fat

Fat – our ancestors' friend

The ability to store fat was essential for our ancestors' survival – they could not rely on food always being available when they needed it. For example, long periods with no rain could cause many of the plants and animals that hunter-gatherers ate to die. Early farmers were even more vulnerable because they became totally dependent on one source of food (their crops), which could be wiped out overnight in a flood. During these periods of famine they would have to break down their fat stores for energy.

It was therefore helpful if our ancestors were able to store any extra energy they got during seasons when lots of food was available. The more fat they could store, the more likely they would be to survive a famine. And if they survived they could pass on their genes for the ability to store lots of fat to the next generation.

Understanding fat

All cells in the body will contain some fat – fat molecules are essential parts of cell membranes (the outer layer of a cell). This is why it is important to eat some fat.

However, when we talk about body fat we often mean specific fat (adipose) tissue. Adipose tissue is made up of adipocytes, which are cells that are great at storing fat. We all need a certain amount of adipose tissue as it helps to keep the body warm and protect our internal organs. Obesity is not an excess of body weight (i.e. the weight of all our bones, organs, muscles etc.) but an excess of adipose tissue.

Old genes that we can't fit into…

Today, we still have the genes that tell our bodies to store extra energy as fat. Our bodies are preparing us to survive a famine … but that famine never comes. In the UK, food is almost always available and easy to get hold of. Without using much energy we can prepare and eat lots of calorie-rich foods. This makes it easy to take in more energy than we need – and our bodies will store the extra energy as fat. Because we don't have to survive famine anymore the fat stores just keep building up and don't get broken down. Physical activity would also break the fat stores down, but many of us do not have very active lifestyles.

So, together our 'old' genes and 'new' environment lead to us gaining fat, and we can become overweight or obese. The usual response to this is to go on a weight-loss diet (i.e. reduce our calorie intake). This is indeed a good idea but we need to remember that our bodies are still 'programmed' for a time when famines and low food intake threatened our survival. Our bodies have special systems to try to make sure we don't starve, and fat plays an important role in this system…

How do we gain fat (adipose) tissue?

When we eat, the energy from our food can either circulate in our blood to be used straight away or, if more energy is consumed than is immediately needed, the extra energy will be stored. A certain amount of excess energy is stored in the liver but when the liver gets full any extra energy is stored in adipose (fat) tissue.

And how do we lose it?

When we run out of the energy that was circulating in our blood – for example, a few hours after a meal - stored fat can be broken down and used by our body.

Remember that our bodies need energy all the time to stay alive – even when we are asleep our hearts need to keep beating, our lungs need to keep breathing and our brains will keep working. This all requires energy. The more active we are the more energy our bodies will require.

The brain listens to our fat

Adipose tissue doesn't just store fat; it also makes a substance called ***leptin***. Leptin acts a bit like a letter from the adipose tissue to the brain – it travels in the blood to be delivered to the brain. The leptin 'letter' tells the brain that we have fat stored. The more adipose tissue we have (i.e. the more fat is stored) the more leptin will be made. Depending on how much leptin there is, the brain will decide whether we need to eat more food or not and so make us feel hungry or full. If there is enough leptin the brain will stop us feeling hungry and if our leptin levels go down our brain will make us feel hungry so that we go looking for food. For our ancestors this was a helpful way of making sure we would hunt for food when the body's energy stores were low – hunger would make our ancestors look for food. And it stopped us wasting energy by trying to get food when we didn't need it.

The problem is that if we regularly eat too much food and gain fat our brains alter their leptin level counters – the new higher level of leptin is set as 'normal'. Remember that, to our brains, stored fat is good as it will help us to survive. This part of the brain doesn't know that there is a supermarket just around the corner. When we lose even just a little bit of fat, and our leptin levels go down a bit, the brain thinks this is a threat to our survival and makes us feel hungry – so we eat more. This is a common problem that people face when trying to lose weight – after successfully losing a bit of fat their leptin levels fall and they feel very hungry. So they eat even more than usual and gain weight again.

Slimming down to fit our old genes

It seems like our bodies don't want us to lose weight! Not only are we built to hold on to extra energy as fat, our brains then work to stop us losing the fat, even though it has harmful effects on the rest of the body.

Unfortunately we can't stop these responses, but being aware of why we feel hungry and recognising that this doesn't necessarily mean that we need more food can help us when we try to lose weight. We can either try to ignore the feelings of hunger and stick to planned meals, or try eating foods that make us feel fuller for longer – these are foods that are high in fibre, a substance found in plants. **High fibre foods** take a long time to pass through our bodies as humans cannot break down fibre very easily, indeed much of the fibre we eat passes through us undigested. Therefore, high fibre foods are a good choice to make us feel full without giving a lot of calories (but watch out for the other ingredients of meals or snacks that contain high fibre).

High fibre foods include fruit and vegetables, pulses (such as lentils and beans), nuts and seeds, and whole grains.

Appendix 3.5 Physical activity narrative (Study 1)

John

A couple of months ago, John had an NHS Health Check and was told he was at high risk of developing type 2 diabetes.

"I was quite shocked when the nurse showed me my results. I mean, I felt fine, just normal. I knew I was carrying a bit of extra weight – my 'spare tyre', the wife called it – but nothing major. I work long hours in an office and have to be at my computer all day. Then, because I live 30 miles away from where I work, I have to drive if I want to get home at a reasonable time. So it wasn't that I didn't want to be more active, it was just that going to the gym or whatever wasn't really feasible.

And then when the nurse suggested looking at this website about evolution and health I thought 'Oh here we go, the latest health fad and this time it sounds like they want me to go hunting deer for dinner or something!' But when I went to the site, it wasn't like that at all. It made sense to me that the human body takes a long time to adapt to changes in the environment. And when I think what life was like when I was a lad and how different it is now, with all the computers and things, it's clear to see that our environment is changing a lot, very quickly. I'd never really thought about what effect all this new technology was having on our bodies and seeing that, actually, we had evolved to rely on being active to help our bodies function was a bit of a surprise. I hadn't realised that we need muscle to lower our blood sugar – I just thought exercise was for losing weight and keeping the heart ticking over. The website really made me see that, even though I was quite big, I probably didn't have much muscle.

So I decided to do something about it. I obviously couldn't cycle to work but I have started parking a few blocks away, giving me a 5 minute walk to the office. If I need to speak to someone in another part of the building I always get up and go to see them rather than phoning or emailing, like I used to. And I make sure that I get up from my desk at least once an hour, even if it's just to get a cuppa. It doesn't sound like much but all these little things add up. Before I would only go up and down the stairs at work once a day – to get to my office in the morning and then going home. But now, I'm up and down about 12 times a day to see people on different floors or to use the toilets on the floor below rather than the ones near my office. I even printed out one of the pictures from the website – of a muscly hunter – and stuck it to my computer screen. That sounds a bit daft but it just helps remind me to think about my muscles!

A few people at work did find it odd when I started coming to see them instead of phoning but I just joked that it was 'cause I wanted to see their lovely faces! Some guessed it was a fitness thing, which I got a bit of stick for, but actually most of them have started getting up more now too.

And I've just been back to the nurse and my risk score has gone down a bit. I've still got a way to go but I found that quite motivating – I've managed to make a difference to my health just by making a few small changes. So I'm going to try making a few more changes to really get my risk down. I also found it surprising how quickly climbing the stairs got easier – I never found it hard exactly before but now I can just take them 2 at a time without even thinking about it. And, I didn't expect this, but taking a quick break from my computer screen actually seems to help me concentrate – so I might even be more productive!"

Appendix 3.6 Diet narrative (Study 1)

Cathy

Cathy had her NHS Health Check 6 months ago and was told she was at high risk for developing type 2 diabetes and cardiovascular disease.

"I was annoyed, more than anything, when the GP told me my risk score. My weight has been something I've battled with for years and I've tried just about every diet going. The last time I managed to lose weight was for my daughter's wedding a year ago – I really wanted to look my best for the photos and I did drop 3 stone. But I was following this miserable diet with none of the foods I like and seemed to constantly feel hungry. So after the wedding I didn't stick to it and the weight just crept back on. Saying that though, it's not like I ate a lot of burgers and chips or something – I always tried to have the lower fat or sugar free options to keep down the calories. So this risk score was just sort of rubbing salt in the wound.

And when the doctor suggested looking at this evolution and health website I felt like saying 'What's the point? It'll just be about another stupid diet that I can't stick to.' But, out of curiosity I suppose, I did have a look at the site and it wasn't what I was expecting at all. I'd never thought about why we feel hungry or like sweet things before but it made sense that these reactions would have helped our ancestors survive. And it felt like a light had been turned on to realise that, actually, just because I was feeling hungry or craved a chocolate biscuit didn't mean I was weak-willed or lacked determination – they were natural responses.

Comparing the foods I was eating with what our ancestors ate was helpful – I could see that the low calorie snack bars and biscuits weren't filling like the fibrous foods our bodies were adapted to. And although I thought I was being really good at sticking to small portions at meal times, most of the meals I made were low fibre too and often didn't have much protein, so I'd soon feel hungry again. But I've made some changes now, trying to include more fibre and protein in my meals with nuts, beans, fish and lots of vegetables. I have slightly bigger portions now but I don't think they're high in calories, because most of the bulk comes from the beans and veg. This helps to fill me up for longer. When I'm in the supermarket or a café looking at different foods, I try to ask myself 'Is this anything like what my ancestors would have eaten?' And if it isn't, say the ingredients list includes a load of 'modified' things, 'stabilisers' and funny chemicals, or it's obvious there's a load of sugar in it, then I won't have it.

My husband wasn't exactly supportive at first as he thought it would just be another fad diet that I'd try for a couple of weeks. And we have had a bit of trial and error with the high fibre foods – we've established that neither of us is keen on lentils. I do still get hungry between meals sometimes too and I'm afraid I have a bit of a sweet tooth so it's hard not to reach for biscuits at these times, even though I try to make sure there are always fruits or nuts for healthier snacks.

But on the whole it's going well. Filling meals and few snacks is just part of the routine now. I don't feel like I'm following 'a diet' and I've actually found some interesting new foods through trying out higher fibre recipes. I still have a night out with the girls occasionally, when I don't worry about sugar contents or fibre and I think that's fine once in a while. Most importantly, my risk score has gone down and I've lost a bit of weight – nothing drastic but I've managed to keep it off. That's boosted my confidence a bit and it feels good to fit into a smaller dress size."

Appendix 3.7 Study 1 Interview schedule

Thank you for agreeing to take part in this study. Before we start I just want to reassure you that you do not have to answer a question if you don't feel comfortable to and if you would like to take a break or stop the interview at any time that is absolutely fine, just let me know. I'm going to be showing you some resources – pictures and text - that we've developed for a health programme. These are just drafts, so they aren't perfect but we would like your feedback so that we know what bits work well and what bits need some attention. Please just say what you think, good or bad! I'll give you the resources and let you look at or read them – please take as long as you need to do this - then I'll ask you some questions on them. I won't be testing you, just asking for your opinions.

To keep the time of these interviews down a bit we are splitting participants in to two conditions; the eventual intervention will have resources on both diet and physical activity but for this study participants will be shown resources on one or the other topic, plus some introductory resources, which everyone sees. You have been randomly assigned to see resources on [diet or physical activity].

Ok, we'll start with some graphics …

Present first main concept graphic

Part 1 – Main concept resources

1.1 Do you think it is attention grabbing? Why/why not?

[Prompts: Layout/image. Title/taglines. Use of facts/stats? Would they stop and look at it?]

1.2 Do you find it attractive? Why/why not?

[Prompts: Layout/text/image/clarity – style, colour.]

1.3 What is/are the main thing(s) this graphic conveys to you?

[Try to get a sense of how clear they find it, how it makes them feel, does it make them think about it in terms of society or individual?]

1.4 Does it make you think about your own life at all? *[Is it relevant?]*

- *Repeat for each main concept graphic*

Ok, now I've got some written information I'd like you to read, again, take as long as you need. There is a pencil there for you if you'd like to note where any clear or unclear, or bits you like and don't like.

- Present main concept text –

1.5 Firstly, was it easy to understand? Were there unclear parts? *[style, tone, headings?]*

1.6 Did you find it interesting? What parts were/weren't?

1.6.1 Were there any parts where you thought 'I'd like to know more about that'?

1.7 How did the information fit with what you already believed/knew?

[Prompt: was it completely new, did any of it seem to contradict what you thought about health? Were there surprising parts?]

Try to find out what they felt were the <u>main influences on their health</u>

1.7.1 Was the information believable/credible?

1.8 What were the key points you, personally, took from the information?

1.9 Did the information make you think about your own life at all? [If 'yes' – what did it make you think about?]

1.9.1 Did it make you think about anything else? [If 'yes' – what else?]

- Show all main concept graphics again -

1.10 Now that you know a bit more about the concepts behind these graphics, do you have any further thoughts on them? [Prompts: which seems most aligned with the information?]

1.11 Which is/are your favourite resource(s)? Why?

Part 2 – Physical activity or diet resources

Ok, I've got some more graphics here - these are much rougher and will obviously be made in a more professional style but it is the basic content that we are interested in here…

- Present first PA/diet graphic –

2.1 Do you have any thoughts on the look or the layout of that graphic? [Is it easy to understand/follow?]

2.2 What is/are the main thing(s) this graphic conveys to you? [Try to get as specific an answer as possible?]

2.3 Does it make you think about your own life at all?

- *Repeat for all graphics*

I've got some more text for you now

- Present PA/diet text –

2.4 Was it easy to understand? Were there unclear parts?

2.5 Did you find it interesting? What parts were/weren't?

2.5.1 Were there any parts where you thought 'I'd like to know more about that'?

2.6 How did the information fit with what you already believed/knew?

[Prompt: was it completely new, did any of it seem to contradict what you thought about health?]

2.6.1 Was the information believable/credible?

2.7 What were the key points you, personally, took from the information?

2.8 Did the information make you think about your own life at all? [If 'yes' – what did it make you think about?]

2.8.1 Did it make you think about anything else? [If 'yes' – what else?]

- Present all PA/diet graphics again –

2.9 Now that you know a bit more about the concepts behind these graphics, do you have any further thoughts on them? [Prompts: which best illustrates the information?]

Now I just have one last page of text for you to read

- Present PA/diet narrative –

2.10 Was the story believable?

2.11 What did you think of John (Cathy)? (like/dislike)

2.11.1 Did you feel you could relate to him/her at all?

2.13 How did the story make you feel? (engagement)

2.14 Does this make you think any differently about the relevance of the resources you just saw?

2.14.1 Can you see any problems for you if you were to make the changes John (Cathy) did?

2.15 Do you think this story is a good way of illustrating some of the concepts covered in the informational text you read earlier?

Part 3 – General intervention

Finally, thinking about all the resources you've seen today

3.1 Do you think these resources come across as different from other health messages? In what way?

3.2 Was looking at health from an evolutionary perspective useful to you? *[try not to lead responses]*

3.3 Based on the information, can you think of any small changes that you could make to your own life that would make it slightly closer to our ancestors' lives and a bit healthier?

3.4 Could you put yourself in the shoes of someone who is thinking about trying to become more healthy. What do you think is the next step for them - what more do they need to know, or what might they want from us next to help them put these ideas into use? *[Prompts: diet/activity guidelines, activity monitors, mobile apps]*

3.5 We're trying to decide how best to make these resources available to people – one option is a website, another is a booklet that could be given out by health professionals or available in pharmacies. What would you prefer?

Okay, that's the end of my questions, thank you very much for all your responses. Is there anything you would like to add or to ask me? **Present questionnaire 1.**

Appendix 3.8 Study 1 Questionnaire 1

(Delivered immediately after interview)

Firstly, please provide us with a little background information by ticking the relevant boxes or providing an answer as indicated.

1.1 Gender: Male ☐ Female ☐

1.2 Age: ___________

1.3 Height: ___________ **1.4 Weight:** ___________ **1.5 Waist circumference:** __________

1.6 What is your ethnic group?

White	☐	Black/Black British	☐
Asian/British Asian	☐	Mixed	☐
Other	☐		

1.7 What is your marital status?

Single	☐	Stable relationship (unmarried)	☐
Married/civil partnership	☐	Divorced/separated	☐
Widowed/widower	☐		

1.8 What is your employment status?

Self-employed	☐	Unemployed (looking for work)	☐
Employed	☐	Unemployed (not looking for work)	☐
Student	☐	Unable to work	☐
Retired	☐	Prefer not to say	☐

1.9 What is your highest educational qualification?

No formal qualifications	☐	Bachelors degree/PGCE	☐
GCSE/O level or equivalent	☐	Masters/postgraduate qualification	☐
A level/NVQ level 3 or equivalent	☐	Doctorate/advanced	☐
HNC/HND/dipHE or equivalent professional qualification	☐		

1.10 Thinking about your knowledge before the interview, did you consider yourself to have a better understanding of evolution than the average UK adult? If so, please briefly explain why (e.g. teach evolution, interested in natural history).

No ☐ Yes ☐ ______________________________________

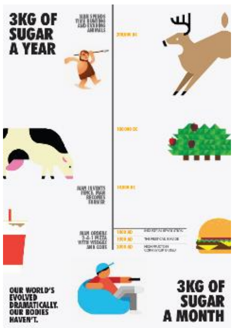
____

The following questions are about the graphics you were shown in the interview. Feel free to have another look at the graphics while completing these questions.

Please tick the most appropriate box for each question.

Graphic 1: Timeline

Do you find this graphic …



2.1 attention grabbing?

Not at all attention grabbing	Not very attention grabbing	Neither attention grabbing nor not	Quite attention grabbing	Very attention grabbing
☐	☐	☐	☐	☐

2.2 attractive (nice to look at)?

Very unattractive	Quite unattractive	Neither attractive nor unattractive	Quite attractive	Very attractive
☐	☐	☐	☐	☐

2.3 easy to understand?

Very difficult to understand	Quite difficult to understand	Neither easy nor difficult to understand	Quite easy to understand	Very easy to understand
☐	☐	☐	☐	☐

2.4 interesting?

Very uninteresting	Quite uninteresting	Neither interesting nor uninteresting	Quite interesting	Very interesting
☐	☐	☐	☐	☐

2.5 relevant to you and your life? (i.e. does it make you think about your life?)

Very irrelevant	Quite irrelevant	Neither relevant nor irrelevant	Quite relevant	Very relevant
☐	☐	☐	☐	☐

Graphic 2: Half ancestor, half modern face

Do you find these graphics …

3.1 attention grabbing?

Not at all attention grabbing	Not very attention grabbing	Neither attention grabbing nor not	Quite attention grabbing	Very attention grabbing
☐	☐	☐	☐	☐

3.2 attractive (nice to look at)?

Very unattractive	Quite unattractive	Neither attractive nor unattractive	Quite attractive	Very attractive
☐	☐	☐	☐	☐

3.3 easy to understand?

Very difficult to understand	Quite difficult to understand	Neither easy nor difficult to understand	Quite easy to understand	Very easy to understand
☐	☐	☐	☐	☐

3.4 interesting?

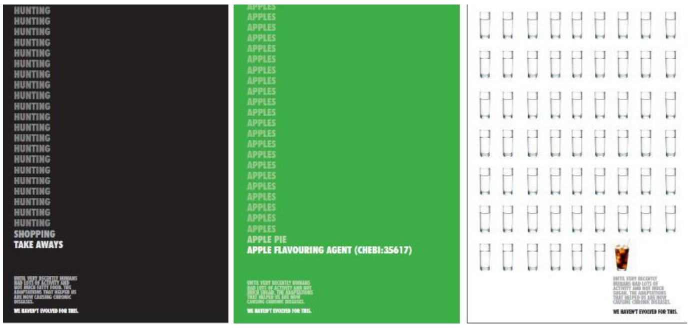
Very uninteresting	Quite uninteresting	Neither interesting nor uninteresting	Quite interesting	Very interesting
☐	☐	☐	☐	☐

3.5 relevant to you and your life? (i.e. does it make you think about your life?)

Very irrelevant	Quite irrelevant	Neither relevant nor irrelevant	Quite relevant	Very relevant
☐	☐	☐	☐	☐

Graphic 3: Lists

Do you find these graphics …



4.1 attention grabbing?

Not at all attention grabbing	Not very attention grabbing	Neither attention grabbing nor not	Quite attention grabbing	Very attention grabbing
☐	☐	☐	☐	☐

4.2 attractive (nice to look at)?

Very unattractive	Quite unattractive	Neither attractive nor unattractive	Quite attractive	Very attractive
☐	☐	☐	☐	☐

4.3 easy to understand?

Very difficult to understand	Quite difficult to understand	Neither easy nor difficult to understand	Quite easy to understand	Very easy to understand
☐	☐	☐	☐	☐

4.4 interesting?

Very uninteresting	Quite uninteresting	Neither interesting nor uninteresting	Quite interesting	Very interesting
☐	☐	☐	☐	☐

4.5 relevant to you and your life? (i.e. does it make you think about your life?)

Very irrelevant	Quite irrelevant	Neither relevant nor irrelevant	Quite relevant	Very relevant
☐	☐	☐	☐	☐

Graphic 4: Future Figures

Do you find these graphics …

5.1 attention grabbing?

Not at all attention grabbing	Not very attention grabbing	Neither attention grabbing nor not	Quite attention grabbing	Very attention grabbing
☐	☐	☐	☐	☐

5.2 attractive (nice to look at)?

Very unattractive	Quite unattractive	Neither attractive nor unattractive	Quite attractive	Very attractive
☐	☐	☐	☐	☐

5.3 easy to understand?

Very difficult to understand	Quite difficult to understand	Neither easy nor difficult to understand	Quite easy to understand	Very easy to understand
☐	☐	☐	☐	☐

5.4 interesting?

Very uninteresting	Quite uninteresting	Neither interesting nor uninteresting	Quite interesting	Very interesting
☐	☐	☐	☐	☐

5.5 relevant to you and your life? (i.e. does it make you think about your life?)

Very irrelevant	Quite irrelevant	Neither relevant nor irrelevant	Quite relevant	Very relevant
☐	☐	☐	☐	☐

Appendix 3.9 Study 1 Questionnaire 2

(Delivered one week after interview)

Thank you for taking part in the second stage of this study. We would like to know whether the information in the resources that Lis showed you last week was memorable and understandable.

1.1 Thinking about the past week, how often have you thought about the resources and information that you looked at during the interview? (Please tick the most appropriate)

- ☐ Not at all
- ☐ Once or twice
- ☐ A few times only on the first few days after the interview
- ☐ A few times over the full week
- ☐ At some point on most days of the week
- ☐ Every day

1.2 Over the past week, has the information in the interview made you think about the things you do in your own life?

- ☐ No, not at all
- ☐ A little bit, but it didn't seem relevant to me
- ☐ A little bit and it did seem relevant to me
- ☐ I thought about it a lot, but it didn't seem relevant to me
- ☐ I thought about it a lot and felt it was relevant to me

1.3 What information, if any, in the interview particularly made you think or has stayed in your mind?

____

____

____

____

1.4 Have you thought about making any changes to your diet or activity levels as a result of the information?

- ☐ Diet
- ☐ Activity levels
- ☐ Both
- ☐ Neither

1.5 Have you made any changes to your diet or activity levels as a result of the information?

- ☐ Diet
- ☐ Activity levels
- ☐ Both
- ☐ Neither (go to part 2)

1.6 If you have made changes, please tell us what these are:

____

____

____

1.7 Of the resources you were shown last week, what in particular made you decide to make changes?

____

____

____

That's all of the questions, thank you very much for participating. When we receive your responses we will send your Amazon vouchers to you.

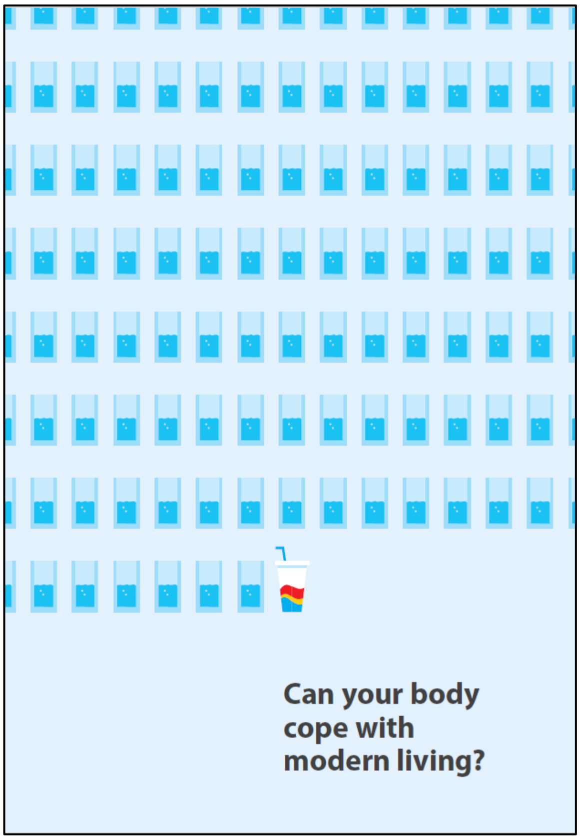
If you have any further comments about the resources or our study, please write them here.

____

____

____

Appendix 4.1 Evolutionary mismatch framed booklet (Study 2)



Contents

Can your body cope with modern life?

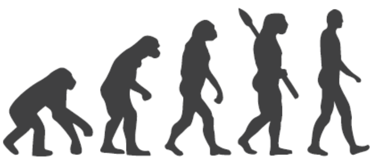
Most of us want to be healthy and try to follow advice on leading a healthy lifestyle. Unfortunately this isn't always easy to do. There are a lot of confusing messages about healthy living out there!

So how could this booklet help? Well, it takes a new perspective – looking at how the human body has evolved and what this means for our health today. It's packed with interesting facts and useful hints to help you understand not just what things we need to do to be healthy but also why these things work…

The changing human body

The human body has been shaped over millions of years of evolution. Along the way our ancestors have lived in many different environments: facing ice ages and tropical heat waves, and eating a huge variety of foods depending on what was available. When the environment changed – for example through climate warming and cooling or when humans travelled to new areas or changed their own environment – **the process of evolution gradually adapted the human body to better suit the new environment.** People with the genes that made their bodies better able to survive and reproduce would pass their genes on to their children, the next generation, making them in turn more likely to survive and reproduce. These helpful genes that improved survival and reproduction are called **adaptive genes.**

Genes are instructions for the body; they tell the body how to develop, affecting many aspects of our lives, from what we look like to how our bodies function.



The process of evolution gradually adapted the human body to better suit new environments

With each new generation of humans, adaptive genes will be spread a bit further, but **it usually takes several hundred generations (and thus thousands of years) for adaptive genes to spread throughout a whole population.** For example, early humans were poorly adapted for walking on two legs as their spines and hips were still very 'ape-like'. Fossil records show how the human body gradually gained an S-shaped spine and large hips, which make us steadier on two feet. But this has taken over 6 million years! Evolution isn't always *that* slow – humans only started to drink milk from other animals less than 10,000 years ago and at first very few adults were able to digest it. Now, a third of the world's population have the genes that allow their bodies to digest cows' milk. But this has still taken several hundred generations to adapt to one small change in our environment.

Humans only started to drink milk from other animals less than 10,000 years ago

So, changes in the environment help to shape the human body but changes to the body take a long time to occur.

This means that:

We will be better suited to things that have stayed the same in our environment
→ *because the human body will have had longer to adapt to them*

We are unlikely to be well suited to things that have changed recently
→ *because the human body won't have had time to adapt*

The changing environment

Changes in the environment help to shape the human body, so it is useful to look at how our environment has changed over the years and see what has had the biggest impact on human lifestyles.

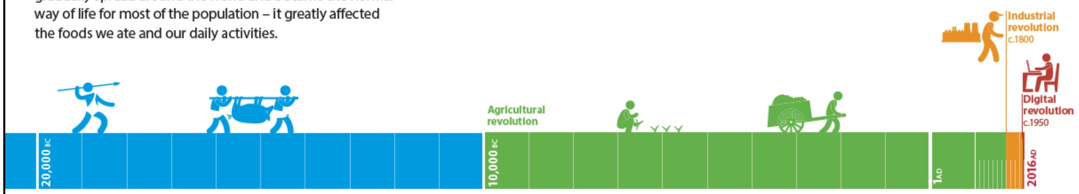
The very first humans separated from the ape family about 6 million years ago and many different species of human have existed since then. Modern humans (*Homo sapiens*) are the only surviving species and evolved from their ancestors about 200,000 years ago.

For most of humans' 6 million year history our ancestors survived by hunting, scavenging and gathering foods and lived in small groups that moved about the land. About 12,000 years ago though, some humans started to grow plants from seeds they collected – they could then eat the plants that they grew. This was the start of farming, also known as the **Agricultural Revolution.** People came to depend more on the plants they grew and less on hunting and gathering for food. They also started to tame wild animals and were able to breed them for food. Farming gradually spread around the world and became the normal way of life for most of the population – it greatly affected the foods we ate and our daily activities.

What do we mean by 'environment'?
We aren't just talking about the countryside but all the conditions that surround us – these can be physical things like people, buildings and technology as well as things that can't be seen.

The next big change to our environment was the Industrial Revolution, which happened much more recently – about 250 years ago. The **Industrial Revolution** saw machines take over the work of humans. Machines were often able to do the work of several humans, much faster and in larger quantities. As more machines were invented they quickly became an everyday part of human lives – affecting everything from the ways we travelled to the foods we ate and how we communicated with each other.

The Industrial Revolution kick-started a great many changes to our environment and these have occurred in a relatively short time (when thinking about other changes in human history). Since the first digital computers were invented, about 60 years ago, the pace of change has become even faster, with many tasks now being completely controlled by computers without the need for humans to lift a finger. Indeed, some people are calling our age – from the 1950s to present day – the **Digital Revolution**.



What these changes mean for us today

Although humans have lived in many different environments throughout our history, 2 important things stayed much the same for our ancestors:

- Physical activity was essential for everyday life
- Foods that were rich in energy (calories) were scarce

But recently our environment has changed a lot, and now these 2 things have completely reversed. Today it is possible to work and get food without moving much at all and energy-rich foods are widely available. **The changes to our environment have happened too quickly for the human body to adapt.** Conditions such as type 2 diabetes and cardiovascular diseases (e.g. high blood pressure, heart disease) can develop as our bodies struggle to cope with our lower levels of activity and larger amounts of high calorie foods.

Our lifestyles have evolved too quickly for our genes to keep up – our bodies are struggling to cope with our modern way of life.

20,000 years ago
Physical activity was essential for everyday life. Foods that were rich in energy were scarce.

Today
Physical activity not essential for everyday life. Foods that are rich in energy are readily available.

Coping with change

We don't want to change our environment back to what it was thousands or even hundreds of years ago – and we probably wouldn't be able to anyway. Many modern advances have been good for our health (and they certainly make things easier for us). For example, we can quickly access safe, clean drinking water and immunisations have greatly lowered the spread of deadly diseases like measles. These positive changes have led to the rise in life expectancy of humans – we are living longer than any of our ancestors have done before. However, although we're living longer, more people are spending their later life in poor health and disability as diseases such as type 2 diabetes and cardiovascular disorder are becoming more common.

But we can make a few simple changes to our lifestyles – **making our diets and physical activity levels slightly more like those of our ancestors** – that will help keep us healthy for longer, so we can enjoy all the benefits of modern technology.

Look out for the **Tips from our ancestors** pages in this booklet for helpful hints on healthy living

How do our activities compare?

Have a look at how our ancient ancestors' lifestyles compare with our grandparents' and our own

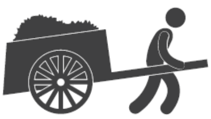
	Hunter-Gatherer Before Agricultural Revolution Before 10,000 BC	Early Farmer After Agricultural Revolution After 10,000 BC	Office Worker After Industrial Revolution 1900 AD	Office Worker – Today After Digital Revolution 2000 AD
Travel	Walking	Walking	Mostly walking	Mostly by car
Work	Building shelters	Manual farm work – tending crops and animals	Mostly seated with some manual work	Mostly seated with little physical activity
Housework	Making animal hide clothes	All cleaning and mending by hand	Most cleaning and mending by hand	Cleaning mostly done by machines
Getting food	Hunting, gathering, building fires, butchering animals	Harvesting crops, milking cows, butchering animals	Walking to different shop daily, preparing most meals by hand	Drive to supermarket once a week or have shopping delivered, much preparation done by machine

Physical effects
Exercises Heart
Improves flexibility
Builds muscle
Strengthens bones

Machines can lead an active life, so we don't have to…

For most of human history physical activity (movement) was essential for getting food and therefore surviving. Early humans had to hunt and kill animals or gather plants to eat. This involved **walking** or running, **stretching** and bending (to pick fruits and vegetables), and carrying what they found back to their group. Because foods did not keep well (there were no fridges) these activities took place **every day** or every other day. All food was prepared by hand – including butchering an animal, which required a lot of strength. Materials for building fires and shelters also had to be collected. Stone tools helped them with these tasks, but making the tools also needed a lot of strength.

After the Agricultural Revolution our ancestors had to work hard to look after their crops and animals. Before machinery was invented all farming had to be done by hand and people needed to skilled in many different tasks – growing and harvesting crops, looking after animals, processing food, mending and making things etc. Early farmers worked long days, every day of the year. So although farming meant our ancestors could eat more, they also had to be **more active.**



1956
Going back just 60 years, before the Digital Revolution, physical activity was still necessary for daily life:

10% Only 10% of families had a car – people walked a lot more, for example to get to shops.

33% Only 33% of households had a washing machine – most people washed their clothes by hand.

15% Only 15% of households had a fridge – people had to go to the shops more often because food did not keep for very long.

The Industrial Revolution started a huge change in the amount of activity humans do in their everyday lives. As machines took over much of the physical labour involved in most jobs, humans were able to specialise in non-physical tasks – the '**office job**' was born. But it wasn't until the Digital Revolution made labour-saving technology cheap and easily available that physical activity became almost entirely an 'optional extra'.

Our environment has now changed so much that physical activity is something we only do if we want to rather than because we have to for work or housekeeping.

Why do we need to be active?

Because physical activity has been such a necessary part of life for most of our ancestors, the human body has adapted to make use of physical activity –

Being active makes the body function better.

Although physical activity is often thought of as something to do if you want to lose weight or not get fat, it **isn't just good for burning calories.**

As the opposite page shows, **activity is important for everyone**, not just people who want to shed a few pounds (although it does help with that too!)

Four important good effects that being active has on the body

1. Building strong bones
– in order to cope with physical activity our bodies make more bone cells. This is important as stronger, denser bones are less likely to break.

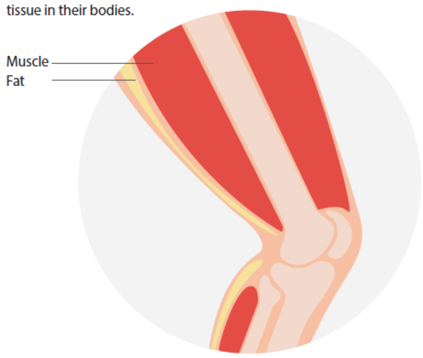
2. Improving flexibility
– physical activity improves our flexibility by strengthening and lengthening the muscles around our joints. This helps us to move more easily and prevents injury.

3. Strengthening the heart
– the heart is also made of muscle (cardiac muscle) and during physical activity this muscle has to work harder to pump blood around the body at a faster rate. In response to the extra work more cells develop to make the heart better able to cope. This helps to prevent heart disease.

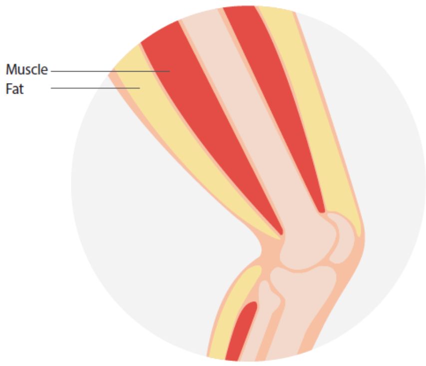
4. Building strong muscles
– physical activity causes the body to make more and bigger muscle cells. This is important because muscle cells are very good at taking sugar out of the blood, which prevents dangerously high blood sugar levels after a meal (one of the signs of type 2 diabetes). Strong muscles also improve our balance and reaction times, which helps prevent us falling over.

Physical activity and muscle

Throughout history, humans have had lots of muscle relative to fat tissue in their bodies.



20,000 years ago



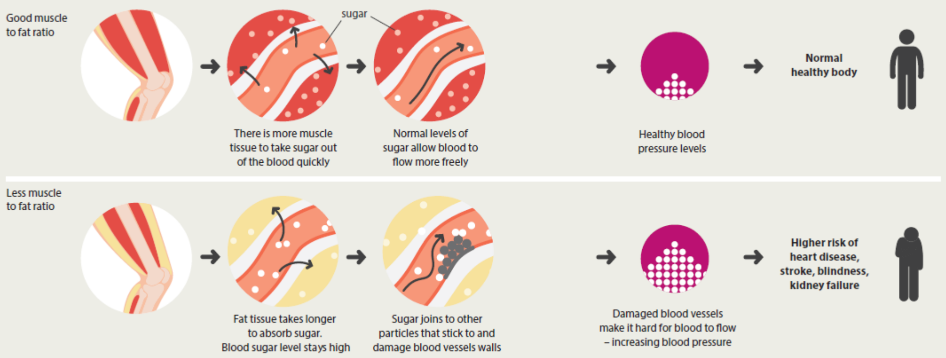
Today

Goodbye muscles…
hello sticky blood cells!

Muscle tissue is very good at taking sugar out of the blood. This process is controlled by a hormone called insulin, which is made in the pancreas. When we eat, our blood sugar levels rise and our pancreas responds by releasing insulin in to the blood. Insulin tells the body's cells to remove sugar from the blood – the cells can then use the sugar for energy or store it. Fat tissue is not as good as muscle tissue at taking sugar from the blood, it needs a lot more insulin than muscle cells in order to take up the same amount of sugar.

If the sugar is not removed, it joins with things in the blood to make new particles that **stick to and damage** the blood vessel walls. This can make it harder for the blood to flow, increasing blood pressure. Damaged blood vessels and high blood pressure can lead to **heart disease** and **stroke** if blood cannot get to the heart muscle or brain. The tiny vessels in the eyes and kidneys are also particularly affected by high blood pressure and if blood sugar levels remain high over a long period of time, **blindness** and **kidney failure** can occur.

What happens to sugar in the blood?



Throughout history, humans have had lots of muscle relative to fat tissue in their bodies. We have evolved to be able to make enough insulin (in our pancreas) for a fairly muscular body. However, in today's environment it is easy to lead very inactive lives and so have low amounts of muscle tissue in our bodies, and relatively higher proportions of fat tissue. This means we need more insulin to take up sugar from the blood quickly enough.

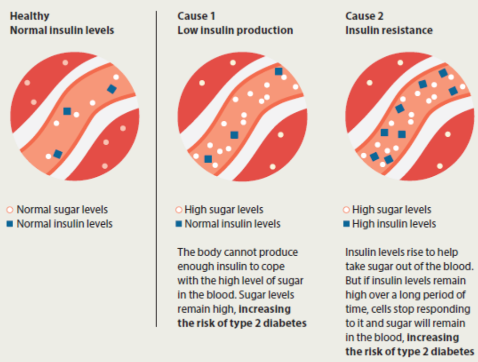
→ **If muscle proportions become too low, the body simply cannot produce enough insulin** – when this occurs it is known as type 2 diabetes.

Some fat tissue is essential. Our ancestors needed fat to keep them warm. However, we need a lot more muscle than fat in our bodies. An imbalance might occur if we have:

- → Too much fat and normal muscle levels (obesity)
- → Too little muscle but normal levels of fat (this person may look thin or 'normal' weight)
- → Both too little muscle and too much fat (this person may look 'normal', overweight or obese).

Type 2 diabetes can also occur if the body's cells become less sensitive to insulin (i.e. when the insulin tells the cells to take up sugar, they don't). This is known as **insulin resistance** and it can also be caused by having too little muscle tissue. Because it will take longer to lower our blood sugar to a safe level after we eat if there is not enough muscle tissue, insulin levels in the blood will also remain high for longer, to keep telling the muscle and fat cells to take up sugar. If insulin levels remain high over a long period of time, cells can become less sensitive to it.

Causes of type 2 diabetes



Tips from our ancestors

We need to be a bit more active, like our ancestors were, in order for our bodies to be healthy. But this doesn't mean we need to totally give up technology or spend hours in the gym each week. Some people like to play sport or go to exercise classes and if you think they might work best for your life then get stuck in! But we can also make some everyday tasks a bit more active or try to rely a little less on technology. Here are some simple ideas to get you started:

Getting food
Our hunter-gatherer ancestors walked miles most days to gather food to eat… 60 years ago most people had to walk to and from several different shops to get their groceries…

…Today, we could park our cars in the farthest space of the supermarket car park and carry our bags rather than using the trolley to take them right to the car. We could walk to shops at the weekend when we have a bit more time or use a basket instead of a trolley if we are only getting a few things.

Work
Early farmers had to harvest their crops by hand … the first factory workers had to stand all day long and operate heavy machinery…

…Working in an office, having to use a computer all day, does make it hard to be active but we could try using every opportunity to get out of our seats – for example, going to talk to people in offices within the same building instead of emailing them, making sure we don't just send one person to fetch the teas and coffees, and walking around when making phone calls. If you use a laptop, try putting it on a higher shelf so that you can stand up for a bit during the day.

Housework
Our ancestors had to make, mend and wash their clothes by hand… before vacuum cleaners were invented people had to sweep and beat carpets…

…Actually housework today can give us quite a good 'work out' – we can carry the vacuum cleaner while using it (unless it is an upright model), make sure we really scrub the bath and tiles, and generally put in the 'elbow grease' rather than doing 'a quick wipe round'. Not only will your body benefit but you'll have a lovely clean house too!

These are just a few ideas – you might not like the sound of all of them but try thinking about your daily routine and other ways that you could make it a bit more active. Although these little changes might not sound like much on their own, if you make several little changes they will add up to have a significant effect on your health.

John

A couple of months ago, John had an NHS Health Check and was told he was at high risk of developing type 2 diabetes.

I was quite shocked when the nurse showed me my results. I mean, I felt fine, just normal. I knew I was carrying a bit of extra weight – my 'spare tyre', the wife called it – but nothing major. I work long hours in an office and have to be at my computer all day. Then, because I live 30 miles away from where I work, I have to drive if I want to get home at a reasonable time. So it wasn't that I didn't want to be more active, it was just that going to the gym or whatever wasn't really feasible.

And then when the nurse suggested looking at this information about evolution and health I thought 'Oh here we go, the latest health fad and this time it sounds like they want me to go hunting deer for dinner or something!' But it wasn't like that at all. It made sense to me that the human body takes a long time to adapt to changes in the environment. And when I think what life was like when I was a lad and how different it is now, with all the computers and things, it's clear to see that our environment is changing a lot, very quickly. I'd never really thought about what effect all this new technology was having on our bodies and seeing that, actually, we had evolved to rely on being active to help our bodies function was a bit of a surprise. I hadn't realised that we need muscle to lower our blood sugar – I just thought exercise was for losing weight and keeping the heart ticking over. The information really made me see that, even though I was quite big, I probably didn't have much muscle.

"I hadn't realised that we need muscle to lower our blood sugar"

So I decided to do something about it. I obviously couldn't cycle to work but I have started parking a few blocks away, giving me a 5 minute walk to the office. If I need to speak to someone in another part of the building I always get up and go to see them rather than phoning or emailing, like I used to. And I make sure that I get up from my desk at least once an hour, even if it's just to get a cuppa. It doesn't sound like much but all these little things add up. Before I would only go up and down the stairs at work once a day – to get to my office in the morning and then going home. But now, I'm up and down about 12 times a day to see people on different floors or to use the toilets on the floor below rather than the ones near my office. I even printed out a picture of a muscly hunter-gatherer and stuck it to my computer screen. That sounds a bit daft but it just helps remind me to think about my muscles!

A few people at work did find it odd when I started coming to see them instead of phoning but I just joked that it was 'cause I wanted to see their lovely faces! Some guessed it was a fitness thing, which I got a bit of stick for, but actually most of them have started getting up more now too.

"I've managed to make a difference to my health just by making a few small changes"

And I've just been back to the nurse and my risk score has gone down a bit. I've still got a way to go but I found that quite motivating – I've managed to make a difference to my health just by making a few small changes. So I'm going to try making a few more changes to really get my risk down. I also found it surprising how quickly climbing the stairs got easier – I never found it hard exactly before but now I can just take them 2 at a time without even thinking about it. And, I didn't expect this, but taking a quick break from my computer screen actually seems to help me concentrate – so I might even be more productive!

Is food our friend or foe?

Food is essential for the survival of all animals. For most of our ancestors, going right back to the apes, food was hard to get and not reliably available – in order to survive in these conditions, many different features evolved in the human body to help us get food and use its energy. But recently our environment has changed a lot and now food is easy to get and reliably available; what's more, the foods that we eat today are often hugely different from what our ancestors ate, even 60 years ago.

Why we evolved a sweet tooth
(and a fatty one … and a salty one …)
Naturally sweet and fatty foods tend to be high in calories – they are said to be 'energy-rich' because a relatively small amount of these foods will provide a lot of energy. This was great for our ancestors, who used up a lot of energy just to gather food. So, gathering sweet and fatty foods helped our ancestors to survive better than gathering foods that were less energy-rich. Because of this humans have evolved to prefer sweet and fatty foods – generally we find them more tasty and pleasant to eat. Salty foods were also hard for our ancestors to find. Salt provides an essential mineral (sodium) that our bodies need to function. Therefore humans developed a preference for salty foods – this helped make sure our ancestors got enough sodium.

Food and drink companies take advantage of our natural preferences and add sugar or sweeteners, salt and fats to their products to make them highly appealing.

Old preferences in a new environment
Today, food is readily available all year round and we tend to lead less active lifestyles, so we do not need as much energy as our ancestors. However, our evolved preferences for sweet and fatty foods still remain, prompting us to choose things like cakes and crisps instead of less energy-rich items. Unlike the naturally sweet and fatty foods that our ancestors had, many foods today tend to have been **processed** or **refined** in ways that remove vitamins, minerals and fibre. This makes the foods taste sweeter and require less chewing but it also means they only give us energy (calories) and little other goodness. Many foods today also have salt added to them – our preference for salty foods, when they are so easily available, causes us to eat too much of it.

How can our preferences lead to harm?

Four important risks of eating lots of sugary, fatty and salty foods:

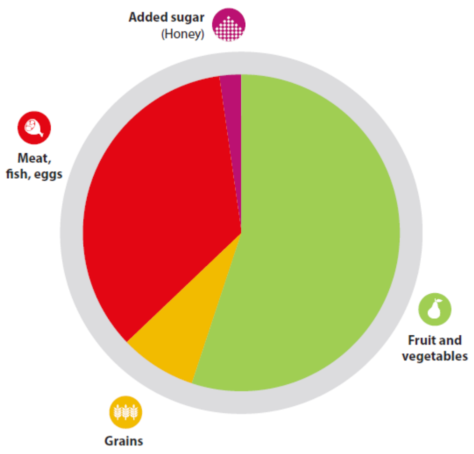
1. Malnutrition
The more artificially energy-rich foods we eat, the fewer nutritious foods we eat. This means that while we may get enough or too much energy, we do not get enough nutrients and vitamins, like protein, fibre and vitamin D.

2. Weight gain
The energy-rich nature of these foods means a very small portion can contain hundreds of calories – it is easy to consume a lot of calories from them without feeling full. This can lead us to put on weight. Being overweight means your heart has to work harder to pump blood around a larger body. This increases the risk of developing heart disease. It can also raise blood pressure, which weakens the blood vessels.

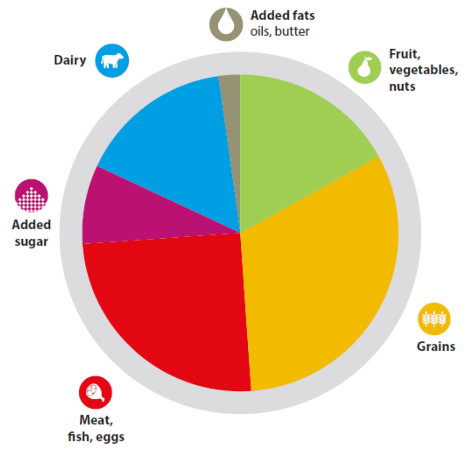
3. High blood sugar
Eating foods that contain a large amount of sugar will raise our blood sugar levels a lot. When this happens our bodies need to send insulin into the blood – insulin tells cells in our bodies to remove sugar from the blood. If we eat a lot of sugar over a long period (for example, by eating sugary foods every few hours) our bodies can struggle to produce enough insulin. This means that sugar will remain in the blood where it can join with other particles and stick to and damage blood vessel walls.

4. High blood pressure
The kidneys take unnecessary salt out of the blood and get rid of it in our urine. But in order to do this the salt needs to be diluted in the blood with water, so the body holds on to water. This results in a lot of liquid flowing through the blood vessels (the blood plus lots of salt and water molecules) – this increases blood pressure and weakens the vessels.

Different diets



20,000 years ago



Today

Tips from our ancestors

It would be impossible to start eating exactly what our hunter-gatherer ancestors did as the animals and plants available to them have evolved as well! It isn't necessary either – our different lifestyles mean that we will need different amounts and types of food. But we can look at the various diets of all our ancestors and see what kinds of foods our bodies are adapted to need and digest. We know that humans need vitamins and minerals, certain fats, protein and fibre, and we have seen that our bodies are not well suited to diets high in sugar, fat and salt. So, we need to reduce our intake of sugary, fatty and salty foods and make sure we get enough of the essential things.

There are lots of little changes we can make to our diets to make them healthier. We can try to ensure that everything we eat contains **at least o**ne good thing – vitamins, minerals, protein, fibre or omega 3 fats. Thinking about what kinds of foods were and weren't available to most of our ancestors can help us to make food choices – generally the more natural and **less processed** or refined a food is, the better it will be.

An example…

Q It's breakfast time and you want something quick and easy. There's cornflakes, honey nut flakes, porridge, muesli or, of course, wholemeal or white toast. Which would be closer to what was available to our ancestors?

A Answer: **Porridge or muesli** would both be good choices. The oats in porridge and muesli have been processed – to remove the husks and roll the grains – but a lot of the fibre remains intact and no sugar is added (unless you add it yourself!) The other cereals are shaped from highly processed grains, mixed with sugar and salt – the cornflakes would be better than the honey nut flakes as they will contain less sugar. The bread for the toast is also made from highly processed grains, and many breads have sugar and salt added – wholemeal toast will contain more fibre than white though.

Which would be closer to what was available to our ancestors?

Our funny relationship with fat

Fat – our ancestors' friend
The ability to store fat was essential for our ancestors' survival – they could not rely on food always being available when they needed it. For example, long periods with no rain could cause many of the plants and animals that hunter-gatherers ate to die. Early farmers were even more vulnerable because they became totally dependent on one source of food (their crops), which could be wiped out overnight in a flood. During these periods of famine they would have to break down their fat stores for energy.

It was therefore helpful if our ancestors were able to store any extra energy they got during seasons when lots of food was available. The more fat they could store, the more likely they would be to survive a famine. And if they survived they could pass on their genes for the ability to store lots of fat to the next generation.

Understanding fat
All cells in the body will contain some fat – fat molecules are essential parts of cell membranes (the outer layer of a cell). This is why it is important to eat some fat.

However, when we talk about body fat we often mean specific fat (adipose) tissue. Adipose tissue is made up of adipocytes, which are cells that are great at storing fat. Obesity is not an excess of body weight (i.e. the weight of all our bones, organs, muscles etc.) but an excess of adipose tissue.

How do we gain fat (adipose) tissue?
When we eat, the energy from our food can either flow in our blood to be used straight away or, if more energy is consumed than is immediately needed, the extra energy will be stored. Some excess energy is stored in the liver but when the liver gets full any more energy is stored in adipose (fat) tissue.

And how do we lose it?
When we run out of the energy that was flowing in our blood – for example, a few hours after a meal - stored fat can be broken down and used.
Remember that our bodies need energy all the time to stay alive – even when we are asleep our hearts need to keep beating, our lungs keep breathing and our brains will keep working. This all requires energy. The more active we are the more energy our bodies will require.

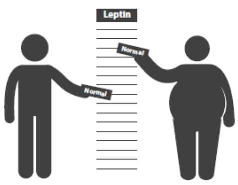
Old genes that we can't fit into…
Today, we still have the genes that tell our bodies to store extra energy as fat. Our bodies are preparing us to survive a famine … but that famine never comes. In the UK, food is almost always available and easy to get hold of. Without using much energy we can prepare and eat lots of calorie-rich foods. This makes it easy to take in more energy than we need – and our bodies will store the extra energy as fat. Because we don't have to survive famine anymore the fat stores just keep building up and don't get broken down. Physical activity would also break the fat stores down, but many of us do not have very active lifestyles.

So, together our 'old' genes and 'new' environment lead us to gain fat, and we can become overweight or obese. The usual response to this is to go on a weight-loss diet (i.e. reduce our calorie intake). This may help us to get back on track but we need to remember that our bodies are still 'programmed' for a time when famines and low food intake threatened our survival. Our bodies have special systems to try to make sure we don't starve, and fat plays an important role in this system…

The brain listens to our fat

Adipose (fat) tissue doesn't just store fat; it also makes a substance called **leptin**. Leptin acts a bit like a letter, which travels in the blood, from the adipose tissue to the brain. The leptin 'letter' tells the brain that we have fat stored. The more adipose tissue we have (i.e. the more fat is stored) the more leptin will be made. Depending on how much leptin there is, the brain will decide whether we need to eat more food or not and so make us feel hungry or full. If there is enough leptin the brain will stop us feeling hungry and if our leptin levels go down our brain will make us feel hungry so that we go looking for food. For our ancestors this was a helpful way of making sure we would hunt for food when the body's energy stores were low – hunger would make our ancestors look for food. And it stopped us wasting energy by trying to get food when we didn't need it.

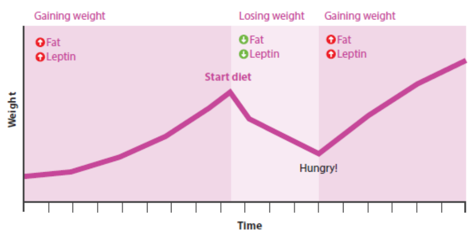
The problem is that if we regularly eat too much food and gain fat our brains alter their leptin level counters – the new higher level of leptin is set as 'normal'. Remember that, to our brains, stored fat is good as it will help us to survive.



Where is your 'normal' level of leptin?'

This part of the brain doesn't know that there is a supermarket just around the corner. When we lose even just a little bit of fat, and our leptin levels go down a bit, the brain thinks this is a threat to our survival and makes us feel hungry – so we eat more. This is a common problem that people face when trying to lose weight – after successfully losing a bit of fat their leptin levels fall and they feel very hungry. So they eat even more than usual and gain weight again.

What happens when we crash diet?



Tips from our ancestors

Slimming down to fit our old genes
It seems like our bodies don't want us to lose weight! Not only are we built to hold on to extra energy as fat, our brains then work to stop us losing the fat, even though it has harmful effects on the rest of the body.

Unfortunately we can't stop these responses, but being aware of why we feel hungry and recognising that this doesn't necessarily mean that we need more food can help us when we try to lose weight. We can either try to ignore the feelings of hunger and stick to planned meals, or try eating foods that make us feel fuller for longer – these are foods that are high in fibre, a substance found in plants. Humans cannot break down fibre very easily, indeed much of the fibre we eat passes through us undigested. So high fibre foods are a good choice to make us feel full without giving a lot of calories (but watch out for the other ingredients of meals or snacks that contain high fibre).

Good sources of fibre are:

- fruit (fresh and dried)
- vegetables
- pulses, such as lentils, chickpeas and beans
- nuts and seeds
- whole grains

It is best to increase the amount of fibre in your diet gradually – the body needs a little time to adjust to a change from a low-fibre to a high-fibre diet.

Most of these foods contain a mixture of insoluble and soluble fibre – and we need both. Insoluble fibre adds bulk to food, making us feel full and also helping food to move through the gut more easily. Soluble fibre turns into a gel in the stomach and helps to slow the absorption of food through the gut wall into the blood – this prevents the blood sugar levels rising rapidly to levels that, as the previous pages have shown, can be hard for the body to cope with.

Here are some tips to help you get more fibre …

- Start the day with porridge or a high-fibre cereal topped with fruit and seeds
- Make wholegrain foods the rule and refined grains the exception – swap brown for white rice and choose wholemeal rather than white bread
- If you need to snack between meals, choose fruit or cut up some fresh vegetables to have with a dip.
- Try adding lentils and beans to soups and stews
- Add extra vegetables when making pasta sauces, curries etc.




Cathy

Cathy had her NHS Health Check 6 months ago and was told she was at high risk for developing type 2 diabetes and cardiovascular disease.

"I was annoyed, more than anything, when the GP told me my risk score. My weight has been something I've battled with for years and I've tried just about every diet going. The last time I managed to lose weight was for my daughter's wedding a year ago – I really wanted to look my best for the photos and I did drop 3 stone. But I was following this miserable diet with none of the foods I like and seemed to constantly feel hungry. So after the wedding I didn't stick to it and the weight just crept back on. Saying that though, it's not like I ate a lot of burgers and chips or something – I always tried to have the lower fat or sugar free options to keep down the calories. So this risk score was just sort of rubbing salt in the wound.

And when the doctor suggested looking at this information on evolution and health I felt like saying 'What's the point? It'll just be about another stupid diet that I can't stick to.' But, out of curiosity I suppose, I did have a look at the booklet and it wasn't what I was expecting at all. I'd never thought about why we feel hungry or like sweet things before but it made sense that these reactions would have helped our ancestors survive. And it felt like a light had been turned on to realise that, actually, just because I was feeling hungry or craved a chocolate biscuit didn't mean I was weak-willed or lacked determination – they were natural responses.

"Just because I craved a chocolate biscuit didn't mean I lacked determination – they were natural responses"

Comparing the foods I was eating with what our ancestors ate was helpful – I could see that the low calorie snack bars and biscuits weren't filling like the fibrous foods our bodies were adapted to. And although I thought I was being really good at sticking to small portions at meal times, most of the meals I made were low fibre too and often didn't have much protein, so I'd soon feel hungry again. But I've made some changes now, trying to include more fibre and protein in my meals with nuts, beans, fish and lots of vegetables. I have slightly bigger portions now but I don't think they're high in calories, because most of the bulk comes from the beans and veg. This helps to fill me up for longer. When I'm in the supermarket or a café looking at different foods, I try to ask myself 'Is this anything like what my ancestors would have eaten?' And if it isn't, say the ingredients list includes a load of 'modified' things, 'stabilisers' and funny chemicals, or it's obvious there's a load of sugar in it, then I won't have it.

"I don't feel like I'm following 'a diet' and I've actually found some interesting new foods"

My husband wasn't exactly supportive at first as he thought it would just be another fad diet that I'd try for a couple of weeks. And we have had a bit of trial and error with the high fibre foods – we've established that neither of us is keen on lentils. I do still get hungry between meals sometimes too and I'm afraid I have a bit of a sweet tooth so it's hard not to reach for biscuits at these times, even though I try to make sure there are always fruits or nuts for healthier snacks.

But on the whole it's going well. Filling meals and few snacks is just part of the routine now. I don't feel like I'm following 'a diet' and I've actually found some interesting new foods through trying out higher fibre recipes. I still have a night out with the girls occasionally, when I don't worry about sugar contents or fibre and I think that's fine once in a while. Most importantly, my risk score has gone down and I've lost a bit of weight – nothing drastic but I've managed to keep it off. That's boosted my confidence a bit and it feels good to fit into a smaller dress size.

Further information

Hopefully this booklet has given you lots to think about! If you would like some more help or information about making healthy lifestyle changes and preventing type 2 diabetes and cardiovascular diseases, here are some useful websites to try:

NHS Choices, Live Well pages: www.nhs.uk/livewell
This website has lots of information about healthy eating, losing weight and becoming more active as well as information on other aspects of healthy living.

Change 4 Life: www.nhs.uk/change4life
This website has lots of tips and some downloadable apps to help you make changes to your diet and become more active.

If you would like to learn more about diabetes and cardiovascular diseases, the following websites give useful guides as well as advice on how to lower your risk of getting these disorders:

British Heart Foundation: www.bhf.org.uk/heart-health/conditions/cardiovascular-disease

Diabetes UK: www.diabetes.org.uk/Type-2-diabetes

NHS Health A–Z:
www.nhs.uk/conditions/Cardiovascular-disease
www.nhs.uk/conditions/Diabetes-type2

Booklet developed by Lis Grey, University of Bath

Appendix 4.2 Non-evolutionary mismatch framed booklet (Study 2)

Contents

Can your body cope with the life you lead?

Most of us want to be healthy and try to follow advice on leading a healthy lifestyle. Unfortunately this isn't always easy to do. There are a lot of confusing messages about healthy living out there!

So how could this booklet help? Well, it takes a new perspective - looking at how our bodies function and what this means for our health today. It's packed with interesting facts and useful hints to help you understand not just what things we need to do to be healthy but also why these things work…

1 Can your body cope with the life you lead?

Thinking about your lifestyle

Today, technology plays a big part in our lives – from cars and computers to telephones and vacuum cleaners. While there are many benefits to technology, much of it has taken away the need for us to be physically active and even encourages us to spend the day sitting down for long periods.

We are also fortunate to live in a society where food is easily available – from supermarkets, cafés, restaurants, fast-food outlets… However, a lot of the food on offer is very rich in energy (calories) and, with daily life providing less opportunity to burn calories, this can lead us to eat too much.

Conditions such as type 2 diabetes and cardiovascular diseases (e.g. high blood pressure, heart disease) can develop as our bodies struggle to cope with our lower levels of activity and larger amounts of high calorie foods. **By making a few simple changes to our lifestyles** – to increase our activity levels and make our diets a bit healthier – we can significantly **reduce our risk** of developing type 2 diabetes and cardiovascular diseases.

T Look out for the **Tips** pages in this booklet for helpful hints on healthy living.

Why do we need to be active?

Although physical activity is often thought of as something to do if you want to lose weight or not get fat, it **isn't just good for burning calories.**

Activity is important for everyone, not just people who want to shed a few pounds (although it does help with that too!)

Four important good effects that being active has on the body

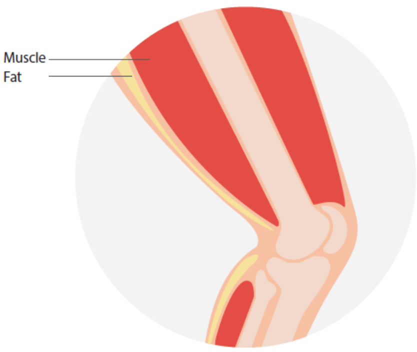
1. Building strong bones
– in order to cope with physical activity our bodies make more bone cells. This is important as stronger, denser bones are less likely to break.

2. Improving flexibility
– physical activity improves our flexibility by strengthening and lengthening the muscles around our joints. This helps us to move more easily and prevents injury.

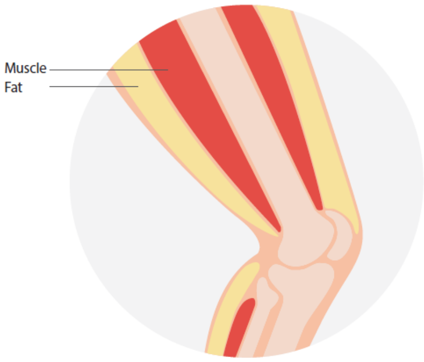
3. Strengthening the heart
– the heart is also made of muscle (cardiac muscle) and during physical activity this muscle has to work harder to pump blood around the body at a faster rate. In response to the extra work more cells develop to make the heart better able to cope. This helps to prevent heart disease.

4. Building strong muscles
– physical activity causes the body to make more and bigger muscle cells. This is important because muscle cells are very good at taking sugar out of the blood, which prevents dangerously high blood sugar levels after a meal (one of the signs of type 2 diabetes). Strong muscles also improve our balance and reaction times, which helps prevent us falling over.

Physical activity and muscle



Active person

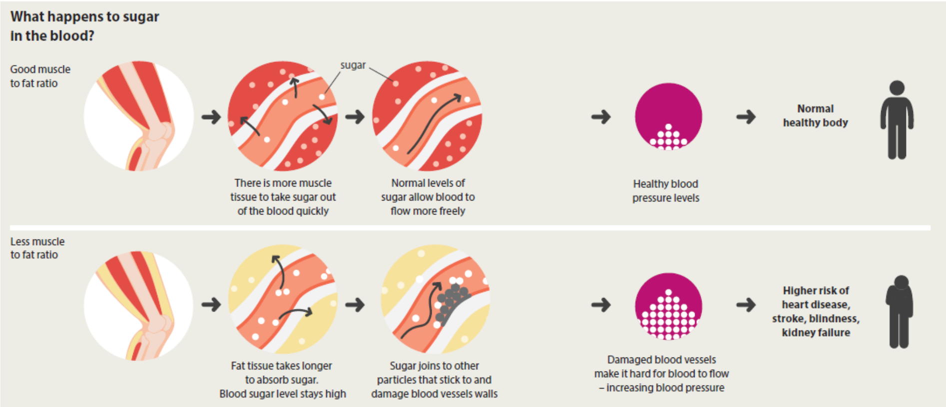


Inactive person

Goodbye muscles… hello sticky blood cells!

Muscle tissue is very good at taking sugar out of the blood. This process is controlled by a hormone called insulin, which is made in the pancreas. When we eat, our blood sugar levels rise and our pancreas responds by releasing insulin in to the blood. Insulin tells the body's cells to remove sugar from the blood – the cells can then use the sugar for energy or store it. Fat tissue is not as good as muscle tissue at taking sugar from the blood, it needs a lot more insulin than muscle cells in order to take up the same amount of sugar.

If the sugar is not removed, it joins with things in the blood to make new particles that **stick to and damage** the blood vessel walls. This can make it harder for the blood to flow, increasing blood pressure. Damaged blood vessels and high blood pressure can lead to **heart disease** and **stroke** if blood cannot get to the heart muscle or brain. The tiny vessels in the eyes and kidneys are also particularly affected by high blood pressure and if blood sugar levels remain high over a long period of time, **blindness** and **kidney failure** can occur.

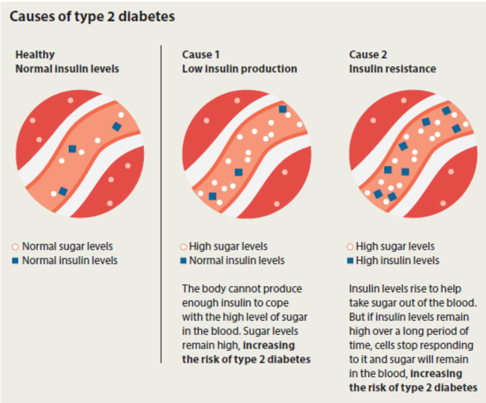


The human body is able to make enough insulin (in our pancreas) for a fairly muscular body. However, if we have inactive lifestyles we will have low amounts of muscle tissue in our bodies, and relatively higher proportions of fat tissue. This means we will need more insulin to take up sugar from the blood quickly enough. If muscle proportions become too low the body simply cannot produce enough insulin – when this occurs it is known as type 2 diabetes.

Some fat tissue is essential. However, we need a lot more muscle than fat in our bodies. An imbalance might occur if we have:

- → Too much fat and normal muscle levels (obesity)
- → Too little muscle but normal levels of fat (this person may look thin or 'normal' weight)
- → Both too little muscle and too much fat (this person may look 'normal', overweight or obese).

Type 2 diabetes can also occur if the body's cells become less sensitive to insulin (i.e. when the insulin tells the cells to take up sugar, they don't). This is known as **insulin resistance** and it can also be caused by having too little muscle tissue. Because it will take longer to lower our blood sugar to a safe level after we eat if there is not enough muscle tissue, insulin levels in the blood will also remain high for longer, to keep telling the muscle and fat cells to take up sugar. If insulin levels remain high over a long period of time, cells can become less sensitive to it.



T

Tips
Making our lives more active

We need to be a bit more active in order for our bodies to be healthy. But this doesn't mean we need to spend hours in the gym each week. Some people like to play sport or go to exercise classes and if you think they might work best for your life then get stuck in! But we can also make some everyday tasks a bit more active or try to rely a little less on technology. Here are some simple ideas to get you started:

Getting food
We could park our cars in the farthest space of the supermarket car park and carry our bags rather than using the trolley to take them right to the car. We could walk to shops at the weekend when we have a bit more time or use a basket instead of a trolley if we are only getting a few things.

Work
Working in offices, having to use a computer all day, does make it hard to be active but we could try using every opportunity to get out of our seats – for example, going to talk to people in offices within the same building instead of emailing them, making sure we don't just send one person to fetch the teas and coffees, and walking around when making phone calls. If you use a laptop, try putting it on a higher shelf so that you can stand up for a bit during the day.

Housework
Housework can actually give us quite a good 'work out' – we can carry the vacuum cleaner while using it (unless it is an upright model), make sure we really scrub the bath and tiles, and generally put in the 'elbow grease' rather than doing 'a quick wipe round'. Not only will your body benefit but you'll have a lovely clean house too!

These are just a few ideas – you might not like the sound of all of them but try thinking about your daily routine and other ways that you could make it a bit more active. Although these little changes might not sound like much on their own, if you make several little changes they will add up to have a significant effect on your health.

John

A couple of months ago, John had an NHS Health Check and was told he was at high risk of developing type 2 diabetes.

I was quite shocked when the nurse showed me my results. I mean, I felt fine, just normal. I knew I was carrying a bit of extra weight – my 'spare tyre', the wife called it – but nothing major. I work long hours in an office and have to be at my computer all day. Then, because I live 30 miles away from where I work, I have to drive if I want to get home at a reasonable time. So it wasn't that I didn't want to be more active, it was just that going to the gym or whatever wasn't really feasible.

"I hadn't realised that we need muscle to lower our blood sugar"

And then when the nurse suggested looking at this information about how my lifestyle affects my body, I thought 'Oh here we go, the latest health fad and this time it sounds like they want to give me a science lesson!' But it wasn't like that at all. I'd never really thought about what effect my lifestyle was having on my body and seeing that, actually, we need to be active to help our bodies function was a bit of a surprise. I hadn't realised that we need muscle to lower our blood sugar – I just thought exercise was for losing weight and keeping the heart ticking over. The information really made me see that, even though I was quite big, I probably didn't have much muscle.

So I decided to do something about it. I obviously couldn't cycle to work but I have started parking a few blocks away, giving me a 5 minute walk to the office. If I need to speak to someone in another part of the building I always get up and go to see them rather than phoning or emailing, like

I used to. And I make sure that I get up from my desk at least once an hour, even if it's just to get a cuppa. It doesn't sound like much but all these little things add up. Before I would only go up and down the stairs at work once a day – to get to my office in the morning and then going home. But now, I'm up and down about 12 times a day to see people on different floors or to use the toilets on the floor below rather than the ones near my office. I even printed out a picture of sticky blood cells and stuck it to my computer screen. That sounds a bit daft but it just helps remind me to think about my muscles!

A few people at work did find it odd when I started coming to see them instead of phoning but I just joked that it was 'cause I wanted to see their lovely faces! Some guessed it was a fitness thing, which I got a bit of stick for, but actually most of them have started getting up more now too.

And I've just been back to the nurse and my risk score has gone down a bit. I've still got a way to go but I found that quite motivating – I've managed to make a difference to my health just by making a few small changes. So I'm going to try making a few more changes to really get my risk down. I also found it surprising how quickly climbing the stairs got easier – I never found it hard exactly before but now I can just take them 2 at a time without even thinking about it. And, I didn't expect this, but taking a quick break from my computer screen actually seems to help me concentrate – so I might even be more productive!

"I've managed to make a difference to my health just by making a few small changes"

Is food our friend or foe?

Food is essential for survival – but it is not always good for us. Our bodies can lead us to eat more than we should but also struggle to cope with certain types of food – making us ill. Here's how…

Humans have a sweet tooth
(and a fatty one … and a salty one …)
Although we all have different favourite foods, much research has shown that humans have a preference for sweet and fatty foods – generally we find them more tasty and pleasant to eat. Sweet and fatty foods tend to be high in calories – they are said to be 'energy-rich' because a relatively small amount of these foods will provide a lot of energy. Many different sweet and fatty foods are available in shops and cafés today and our preferences prompt us to choose them instead of less energy-rich items. This can be a problem if we do not lead an active life as it can cause us to eat more calories than we use, and so put on weight.

Food manufacturers have also developed ways of processing foods to make them more appealing – they are refined so that they require less chewing and taste sweeter but often their natural vitamins, minerals and fibre are removed. This means that the foods give us energy (calories) but little other goodness. Many foods also have salt added to them – our preference for salty foods, when they are so easily available, causes us to eat too much of it.

Food and drink companies take advantage of our natural preferences and add sugar or sweeteners, salt and fats to their products to make them highly appealing.

Tips
Making changes

We know that we need vitamins and minerals, certain fats, protein and fibre, and we have seen that our bodies are not well suited to diets high in sugar, fat and salt. So, we need to reduce our intake of sugary, fatty and salty foods and make sure we get enough of the essential things.

There are lots of little changes we can make to our diets to make them healthier. One way is to try to ensure that everything we eat contains **at least** one good thing – vitamins, minerals, protein, fibre or omega 3 fats. Generally the more natural and less processed or refined a food is, the better it will be.

An example…

Q It's breakfast time and you want something quick and easy. There's cornflakes, honey nut flakes, porridge, muesli or, of course, wholemeal or white toast. Which would be healthier?

A Answer: **Porridge or muesli** would both be good choices. The oats in porridge and muesli have been processed – to remove the husks and roll the grains – but a lot of the fibre remains intact and no sugar is added (unless you add it yourself!) The other cereals are shaped from highly processed grains, mixed with sugar and salt – the cornflakes would be better than the honey nut flakes as they will contain less sugar. The bread for the toast is also made from highly processed grains, and many breads have sugar and salt added – wholemeal toast will contain more fibre than white though.

Which would be healthier?

Cornflakes

Honey Nut Flakes

Muesli

Porridge

Toast

?

How can our preferences lead to harm?

Four important risks of eating lots of sugary, fatty and salty foods:

1. Malnutrition
The more artificially energy-rich foods we eat, the fewer nutritious foods we eat. This means that while we may get enough or too much energy, we do not get enough nutrients and vitamins, like protein, fibre and vitamin D.

2. Weight gain
The energy-rich nature of these foods means a very small portion can contain hundreds of calories – it is easy to consume a lot of calories from them without feeling full. This can lead us to put on weight. Being overweight means your heart has to work harder to pump blood around a larger body. This increases the risk of developing heart disease. It can also raise blood pressure, which weakens the blood vessels.

3. High blood sugar
Eating foods that contain a large amount of sugar will raise our blood sugar levels a lot. When this happens our bodies need to send insulin into the blood – insulin tells cells in our bodies to remove sugar from the blood. If we eat a lot of sugar over a long period (for example, by eating sugary foods every few hours) our bodies can struggle to produce enough insulin. This means that sugar will remain in the blood where it can join with other particles and stick to and damage blood vessel walls.

4. High blood pressure
The kidneys take unnecessary salt out of the blood and get rid of it in our urine. But in order to do this the salt needs to be diluted in the blood with water, so the body holds on to water. This results in a lot of liquid flowing through the blood vessels (the blood plus lots of salt and water molecules) – this increases blood pressure and weakens the vessels.

Our funny relationship with fat

If we consume more food than we need our bodies will store the extra energy as fat. These stores of fat can be broken down and used for energy at a later time, for example if we do a lot of exercise or go for a long time without eating.

The problem is that, in the UK, food is almost always available and easy to get hold of. Without using much energy we can prepare and eat lots of calorie-rich foods. Many of us are also leading fairly inactive lifestyles. This makes it easy to take in more energy than we need –our bodies store the extra energy as fat and the fat stores just keep building up but don't get broken down.

Understanding fat
All cells in the body will contain some fat – fat molecules are essential parts of cell membranes (the outer layer of a cell). This is why it is important to eat some fat.

However, when we talk about body fat we often mean specific fat (adipose) tissue. Adipose tissue is made up of adipocytes, which are cells that are great at storing fat. Obesity is not an excess of body weight (i.e. the weight of all our bones, organs, muscles etc.) but an excess of adipose tissue.

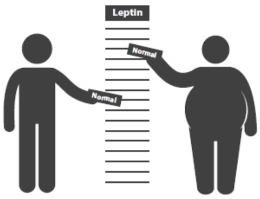
How do we gain fat (adipose) tissue?
When we eat, the energy from our food can either flow in our blood to be used straight away or, if more energy is consumed than is immediately needed, the extra energy will be stored. Some excess energy is stored in the liver but when the liver gets full any more energy is stored in adipose (fat) tissue.

And how do we lose it?
When we run out of the energy that was flowing in our blood – for example, a few hours after a meal - stored fat can be broken down and used.
Remember that our bodies need energy all the time to stay alive – even when we are asleep our hearts need to keep beating, our lungs keep breathing and our brains will keep working. This all requires energy. The more active we are the more energy our bodies will require.

The usual response to this is to go on a weight-loss diet (i.e. reduce our calorie intake). This may help us to get back on track but it is complicated because our bodies have special systems to try to make sure we don't starve, and fat plays an important role in this system…

The brain listens to our fat

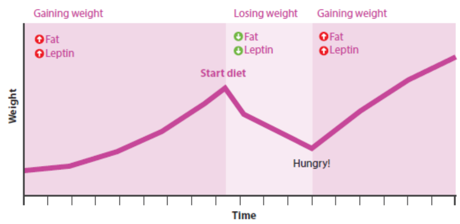
Adipose (fat) tissue doesn't just store fat; it also makes a substance called **leptin**. Leptin acts a bit like a letter, which travels in the blood, from the adipose tissue to the brain. The leptin 'letter' tells the brain that we have fat stored. The more adipose tissue we have (i.e. the more fat is stored) the more leptin will be made. Depending on how much leptin there is, the brain will decide whether we need to eat more food or not and so make us feel hungry or full. If there is enough leptin the brain will stop us feeling hungry and if our leptin levels go down our brain will make us feel hungry so that we go looking for food.



Where is your 'normal' level of leptin?'

The problem is that if we regularly eat too much food and gain fat our brains alter their leptin level counters – the new higher level of leptin is set as 'normal'. To our brains, stored fat is good as it will help us to survive. This part of the brain doesn't know that there is a supermarket just around the corner. When we lose even just a little bit of fat, and our leptin levels go down a bit, the brain thinks this is a threat to our survival and makes us feel hungry – so we eat more. This is a common problem that people face when trying to lose weight – after successfully losing a bit of fat their leptin levels fall and they feel very hungry. So they eat even more than usual and gain weight again.

What happens when we crash diet?



Tips

How to avoid the leptin effect
It seems like our bodies don't want us to lose weight! Not only are we built to hold on to extra energy as fat, our brains then work to stop us losing the fat, even though it has harmful effects on the rest of the body.

Unfortunately we can't stop these responses, but being aware of why we feel hungry and recognising that this doesn't necessarily mean that we need more food can help us when we try to lose weight. We can either try to ignore the feelings of hunger and stick to planned meals, or try eating foods that make us feel fuller for longer – these are foods that are high in fibre, a substance found in plants. Humans cannot break down fibre very easily, indeed much of the fibre we eat passes through us undigested. So high fibre foods are a good choice to make us feel full without giving a lot of calories (but watch out for the other ingredients of meals or snacks that contain high fibre).

Good sources of fibre are:

- fruit (fresh and dried)
- vegetables
- pulses, such as lentils, chickpeas and beans
- nuts and seeds
- whole grains

It is best to increase the amount of fibre in your diet gradually – the body needs a little time to adjust to a change from a low-fibre to a high-fibre diet.

Most of these foods contain a mixture of insoluble and soluble fibre – and we need both. Insoluble fibre adds bulk to food, making us feel full and also helping food to move through the gut more easily. Soluble fibre turns into a gel in the stomach and helps to slow the absorption of food through the gut wall into the blood – this prevents the blood sugar levels rising rapidly to levels that, as the previous pages have shown, can be hard for the body to cope with.

Here are some tips to help you get more fibre…

- Start the day with porridge or a high-fibre cereal topped with fruit and seeds
- Make wholegrain foods the rule and refined grains the exception – swap brown for white rice and choose wholemeal rather than white bread
- If you need to snack between meals, choose fruit or cut up some fresh vegetables to have with a dip.
- Try adding lentils and beans to soups and stews
- Add extra vegetables when making pasta sauces, curries etc.

Cathy

Cathy had her NHS Health Check 6 months ago and was told she was at high risk for developing type 2 diabetes and cardiovascular disease.

I was annoyed, more than anything, when the GP told me my risk score. My weight has been something I've battled with for years and I've tried just about every diet going. The last time I managed to lose weight was for my daughter's wedding a year ago – I really wanted to look my best for the photos and I did drop 3 stone. But I was following this miserable diet with none of the foods I like and seemed to constantly feel hungry. So after the wedding I didn't stick to it and the weight just crept back on. Saying that though, it's not like I ate a lot of burgers and chips or something – I always tried to have the lower fat or sugar free options to keep down the calories. So this risk score was just sort of rubbing salt in the wound.

And when the doctor suggested looking at this information on how my lifestyle affects my body I felt like saying 'What's the point? It'll just be about another stupid diet that I can't stick to.' But, out of curiosity I suppose, I did have a look at the booklet and it wasn't what I was expecting at all. I'd never thought about why we feel hungry before and I didn't realise that humans naturally prefer sweet and fatty foods. It felt like a light had been turned on to realise that, actually, just because I was feeling hungry or craved a chocolate biscuit didn't mean I was weak-willed or lacked determination – they were natural responses.

"Just because I craved a chocolate biscuit didn't mean I lacked determination – they were natural responses"

Thinking about how processed and refined foods were was helpful – I could see that the low calorie snack bars and biscuits weren't filling because they had very little fibre. And although I thought I was being really good at sticking to small portions at meal times, most of the meals I made were low fibre too and often didn't have much protein, so I'd soon feel hungry again. But I've made some changes now, trying to include more fibre and protein in my meals with nuts, beans, fish and lots of vegetables. I have slightly bigger portions now but I don't think they're high in calories, because most of the bulk comes from the beans and veg. This helps to fill me up for longer. When I'm in the supermarket or a café looking at different foods, I try to ask myself 'How much processing has gone into this?' And if the ingredients list includes a load of 'modified' things, 'stabilisers' and funny chemicals, or it's obvious there's a load of sugar in it, then I won't have it.

"I don't feel like I'm following 'a diet' and I've actually found some interesting new foods"

My husband wasn't exactly supportive at first as he thought it would just be another fad diet that I'd try for a couple of weeks. And we have had a bit of trial and error with the high fibre foods – we've established that neither of us is keen on lentils. I do still get hungry between meals sometimes too and I'm afraid I have a bit of a sweet tooth so it's hard not to reach for biscuits at these times, even though I try to make sure there are always fruits or nuts for healthier snacks.

But on the whole it's going well. Filling meals and few snacks is just part of the routine now. I don't feel like I'm following 'a diet' and I've actually found some interesting new foods through trying out higher fibre recipes. I still have a night out with the girls occasionally, when I don't worry about sugar contents or fibre and I think that's fine once in a while. Most importantly, my risk score has gone down and I've lost a bit of weight – nothing drastic but I've managed to keep it off. That's boosted my confidence a bit and it feels good to fit into a smaller dress size.

Further information

Hopefully this booklet has given you lots to think about! If you would like some more help or information about making healthy lifestyle changes and preventing type 2 diabetes and cardiovascular diseases, here are some useful websites to try:

NHS Choices, Live Well pages:
www.nhs.uk/livewell
This website has lots of information about healthy eating, losing weight and becoming more active as well as information on other aspects of healthy living.

Change 4 Life: www.nhs.uk/change4life
This website has lots of tips and some downloadable apps to help you make changes to your diet and become more active.

If you would like to learn more about diabetes and cardiovascular diseases, the following websites give useful guides as well as advice on how to lower your risk of getting these disorders:

British Heart Foundation: www.bhf.org.uk/heart-health/conditions/cardiovascular-disease

Diabetes UK: www.diabetes.org.uk/Type-2-diabetes

NHS Health A-Z:
www.nhs.uk/conditions/Cardiovascular-disease
www.nhs.uk/conditions/Diabetes-type2

Booklet developed by Lis Grey, University of Bath

Appendix 4.3 Study 2 Time 1 questionnaire

N.B. This questionnaire was delivered online via Bristol Online Surveys

Developing information resources to support healthy lifestyle change – questionnaire 1

Thank you very much for offering to take part in our study. Before you begin the first questionnaire, it is important that you understand what participating will involve. The information document we sent you has all the details of the study – please make sure you have read this thoroughly and if you have any questions about it do not hesitate to contact us. Our contact details are given below and are on the information document.

Doctoral researcher	**Other members of the research team**	
Lis Grey	Professor Dylan Thompson	Dr Fiona Gillison
e.b.grey@bath.ac.uk	d.thompson@bath.ac.uk	f.b.gillison@bath.ac.uk
01225 383589	01225 383177	01225 384387

In order to proceed, please read the following statements and select the boxes to confirm them.

I confirm that I have read and understand the Information Document for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	○
I understand that my participation is voluntary and that I am free to withdraw at any time up until 1 month after today and can do so by contacting the researchers.	○
I understand that this project has been reviewed by, and received ethics clearance through, the Research Ethics Approval Committee for Health of the University of Bath	○
I understand that any information I provide will be treated confidentially and stored securely at the University.	○

Developing information resources to support healthy lifestyle change

Questionnaire 1

This questionnaire is made up of several sections with questions that have been designed to give us an idea about your current lifestyle and what you think about certain issues to do with healthy living.

There are **no trick questions**. We simply want to know **your personal feelings and beliefs**. Please read the instructions for each question carefully and respond to all items. Some of the questions might seem a bit repetitive but it is important that you answer them all.

This questionnaire should take less than 30 minutes to complete.

Section 1

Firstly, please provide us with a little background information about you.

Gender: Male ☐ Female ☐

Age: __________

Height (Please state the unit used, e.g. 173cm or 5ft 8in)**:** __________

Weight (Please state the unit used, e.g. 70kg or 11st 7lb)**:** __________

What is your ethnic group?

White ☐ Black/Black British ☐

Asian/British Asian ☐ Mixed ☐

Other ☐

If you selected Other, please specify:

What is your marital status?

Single ☐ Stable relationship (unmarried) ☐

Married/civil partnership ☐ Divorced/separated ☐

Widowed/widower ☐

What is your employment status?

Employed/self-employed (full-time) ☐ Employed/self-employed (part-time) ☐

Student ☐ Retired ☐

Unemployed (looking for work) ☐ Unemployed (not looking for work) ☐

Unable to work ☐ Prefer not to say ☐

What is your highest educational qualification?

No formal qualifications ☐ GCSE/O level or equivalent ☐

A level/NVQ level 3 or equivalent ☐ HNC/HND/dipHE or equivalent ☐

Bachelors degree ☐ Masters/postgraduate qualification ☐

Doctorate/advanced professional qualification ☐

Section 2

Please think about all the **vigorous physical activities** that you do in an average week. Vigorous physical activities refer to activities that take *hard physical effort* and make you *breathe much harder* than normal, e.g. running.

Think *only* about those physical activities that you do for **at least 10 minutes at a time**.

In an average week, **how much time, in total**, do you spend doing **vigorous** physical activities? (please give answer in minutes per week)

____

Think about all the **moderate physical activities** that you do in an average week. Moderate activities refer to activities that take *moderate physical effort* and make you *breathe somewhat harder* than normal, e.g. brisk walking. Think *only* about those physical activities that you do for at least 10 minutes at a time.

In an average week, **how much time, in total**, do you spend doing moderate physical activities? (please give answer in minutes per week)

____

Think about all the **strengthening activities** that you do in an average week. Strengthening activities refer to activities that involve *using body weight* or *working against a resistance*, e.g. exercising with weights and carrying or moving heavy loads such as groceries.

In an average week, on how many days do you do **strengthening** activities? _______

And about how long do you spend doing strengthening activities on these days? (minutes) _______

Do you think that you, personally, need to increase your activity levels?

Yes ☐

No ☐

Are you thinking about making any changes to your activity levels? If yes, please say what changes you are thinking of making.

Yes ☐

No ☐

If yes, please say what changes you are thinking of making.

Thinking about what you eat **in a typical week**, please answer the following.

How often do you …

	Rarely or never	Some days	About half the days in a week	Most days	Every day
eat 5 or more portions of fruit and vegetables a day? (*As a guide, a portion is about a handful*)	0	1	2	3	4
add sugar to your drinks or breakfast cereals?	4	3	2	1	0
drink sweet fizzy drinks?					
eat more than 2 portions of cakes, puddings, sweets, chocolate or biscuits a day?	4	3	2	1	0
choose wholemeal or wholegrain starchy foods (e.g. bread, rice, pasta) rather than white options?	0	1	2	3	4
include pulses (e.g. beans, lentils, chickpeas) in your diet?	0	1	2	3	4

	Rarely or never	Some days	About half the days in a week	Most days	Every day
add salt to food during or after cooking?	4	3	2	1	0
eat pre-prepared meals? (e.g. pre-prepared sandwiches, ready meals or canned soups)	4	3	2	1	0
eat processed meats such as ham or bacon, or smoked fish?	4	3	2	1	0
eat salted snacks, such as crisps or salted nuts?	4	3	2	1	0
choose baked, steamed or grilled options when available, rather than fried foods (e.g. fish and chips)?	0	1	2	3	4
choose foods that are lower in saturated fat rather than the higher saturated fat alternatives (e.g. using sunflower or olive oil rather than butter for cooking)?	0	1	2	3	4

On a scale from 0 to 10, where 0 is not at all healthy and 10 is extremely healthy (couldn't be improved), **how healthy do you think your diet is?**

not at all healthy										extremely healthy
0	1	2	3	4	5	6	7	8	9	10

Are you on a special diet?

Yes ☐

No ☐

[If yes] Please provide brief details of your diet.

Are you thinking about making any changes to your diet?

Yes ☐

No ☐

[If yes] Please tell us what changes you are thinking of making.

Section 3

We are interested in the reasons underlying peoples' **decisions to engage or not engage in physical activity**.

Using the scale below, please indicate **to what extent each of the following items is true for you**.

	Not true for me		Sometimes true for me		Very true for me
It's important to me to be active regularly	0	1	2	3	4
I don't see why I should have to be active	0	1	2	3	4
I am active because it's fun	0	1	2	3	4
I feel guilty when I'm not active	0	1	2	3	4
I'm active because it is consistent with my life goals	0	1	2	3	4
I'm active because other people say I should be	0	1	2	3	4
I value the benefits of physical activity	0	1	2	3	4
I can't see why I should bother being active	0	1	2	3	4
I enjoy my physical activity sessions	0	1	2	3	4
I feel ashamed when I miss an activity session	0	1	2	3	4
I consider physical activity part of my identity	0	1	2	3	4
I take part in physical activity because my friends/family/partner say I should	0	1	2	3	4

Using the scale below, please indicate **to what extent each of the following items is true for you**.

	Not true for me			**Sometimes true for me**	**Very true for me**
I think it is important to make the effort to be active regularly	0	1	2	3	4
I don't see the point in physical activity	0	1	2	3	4
I find physical activity pleasurable	0	1	2	3	4
I feel like a failure when I haven't been physically active in a while	0	1	2	3	4
I consider physical activity a fundamental part of who I am	0	1	2	3	4
I engage in physical activity because others will not be pleased with me if I don't	0	1	2	3	4
I get restless if I don't engage in physical activity regularly	0	1	2	3	4
I think physical activity is a waste of time	0	1	2	3	4
I get pleasure and satisfaction from participating in physical activity	0	1	2	3	4
I would feel bad about myself if I was not making time to engage in physical activity	0	1	2	3	4
I consider physical activity consistent with my values	0	1	2	3	4
I feel under pressure from my friends/family to be physically active	0	1	2	3	4

We are interested in the reasons underlying peoples' **decisions to eat the way they do**.

Using the scale below, please indicate **to what extent each of the following items is true for you**.

	Not true for me		**Sometimes true for me**		**Very true for me**
It's important to me to eat healthily	0	1	2	3	4
I don't see why I should have to eat healthily	0	1	2	3	4
I eat healthily because it's fun	0	1	2	3	4
I feel guilty when I do not eat healthily	0	1	2	3	4
I eat healthily because it is consistent with my life goals	0	1	2	3	4
I eat healthily because other people say I should	0	1	2	3	4
I value the benefits of eating healthily	0	1	2	3	4
I can't see why I should bother eating healthily	0	1	2	3	4
I enjoy eating healthy meals	0	1	2	3	4
I feel ashamed when I eat unhealthy meals or snacks	0	1	2	3	4
I consider eating healthily part of my identity	0	1	2	3	4
I eat healthily because my friends/family/partner say I should	0	1	2	3	4

Using the scale below, please indicate **to what extent each of the following items is true for you**.

	Not true for me		Sometimes true for me		Very true for me
I think it is important to make the effort to eat healthily	0	1	2	3	4
I don't see the point in eating healthily	0	1	2	3	4
I find eating healthily pleasurable	0	1	2	3	4
I feel like a failure when I haven't eaten healthily in a while	0	1	2	3	4
I consider eating healthily a fundamental part of who I am	0	1	2	3	4
I eat healthily because others will not be pleased with me if I don't	0	1	2	3	4
I get uncomfortable or frustrated if I don't eat healthily regularly	0	1	2	3	4
I think eating healthily is a waste of time	0	1	2	3	4
I get pleasure and satisfaction from eating healthily	0	1	2	3	4
I would feel bad about myself if I was not making time to eat healthily	0	1	2	3	4
I consider healthy eating to be consistent with my values	0	1	2	3	4
I feel under pressure from my friends/family to eat healthily	0	1	2	3	4

Section 4

How important do you believe **physical activity** is for the **maintenance of health**?

not at all important									very important
1	2	3	4	5	6	7	8	9	10

How does physical activity affect health? Please select **all** the statements that you agree with *or* one of the last two options.

Physical activity helps to build strong muscles which quickly remove sugar from the blood, preventing the sugar from damaging blood vessels

Physical activity causes more heart muscle cells to grow, making the heart stronger.

Physical activity helps to build a bigger, stronger pancreas that can produce more insulin, which is needed to lower blood sugar levels

Physical activity transforms fat cells into muscle cells, making the body weigh less and so placing less strain on the heart and blood vessels

Physical activity does not affect health

Physical activity does affect health but I am not sure how

How important do you believe **diet** (i.e. what a person eats) is for the **maintenance of health**?

Not at all important									Very important
1	2	3	4	5	6	7	8	9	10

For the following questions please select **all** the statements that you agree with or one of the last two options.

How does fibre intake affect health?

Fibre helps to line the gut wall and prevent free-radicals in food entering the blood stream and attacking cells.
Fibre can slow the absorption of sugar through the gut wall and so prevent spikes in blood sugar levels.
Fibre joins with cholesterol in the blood, preventing it from sticking to blood vessel walls and causing blood clots.
Fibre makes you feel full but can't be digested so can help prevent weight gain.
Fibre intake does not affect health.
Fibre intake does affect health but I'm not sure how.

How does sugar intake affect health?

Sugar acts as a toxin (poison) in the pancreas, attacking the cells that produce insulin. This can lead to diabetes if the pancreas can no longer produce insulin.
If a lot of sugar is eaten over a long period, insulin levels remain high and cells can become less sensitive to it – this insulin resistance leads to type 2 diabetes.
Sugar joins with other particles in the blood and they stick to and damage blood vessel walls
If a lot of sugar is eaten the excess sugar blocks cells in the gut wall, preventing vitamins and minerals in food from being absorbed into the blood.
Sugar intake does not affect health.
Sugar intake does affect health but I'm not sure how.

How does salt intake affect health?

Excess salt can build up on blood vessel walls forming plaques, which limit blood flow and can eventually completely block the vessels (i.e. form a blood clot).
If there are high levels of salt in the blood, water is held rather than excreted – the extra water in the blood increases blood pressure, which weakens blood vessels.
High salt intake causes minerals to be secreted from cells in to the blood stream in order to dilute the salty blood. This means that the cells can't use the minerals.
Salt intake does not affect health.
Salt intake does affect health but I'm not sure how.

Section 5

The following are statements about benefits of physical activity (walking, jogging, swimming, stretching, lifting etc.)

Please state the degree to which you *personally* agree or disagree with the statements.

Physical activity…

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
… Makes me feel better physically	1	2	3	4	5
… Makes my mood better in general	1	2	3	4	5
… Helps me feel less tired	1	2	3	4	5
… Makes my muscles stronger	1	2	3	4	5
… Is something I enjoy doing	1	2	3	4	5
… Gives me a sense of personal accomplishment	1	2	3	4	5
… Makes me more alert mentally	1	2	3	4	5
… Improves my endurance in performing my daily activities (personal care, cooking, shopping, cleaning)	1	2	3	4	5
… Helps to strengthen my bones	1	2	3	4	5

Please state the degree to which you *personally* agree or disagree with the following statements about eating a healthy diet.

If I ate a healthy diet every day…

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
… I would have more energy	1	2	3	4	5
… I would feel healthier and happier	1	2	3	4	5
… I would be able to keep my weight where I want it	1	2	3	4	5
… it would help me live longer	1	2	3	4	5
… I would feel better in my clothes	1	2	3	4	5
… it would improve my health	1	2	3	4	5
… I would have healthier skin, hair or teeth	1	2	3	4	5
… it would take too much time to keep track of foods I have eaten	1	2	3	4	5
… food would not taste as good	1	2	3	4	5
… it would take too long to prepare meals	1	2	3	4	5
… I would have to plan what to eat too far in advance	1	2	3	4	5
… shopping would be too much trouble	1	2	3	4	5
… I would be bored with what I have to eat	1	2	3	4	5
… my food would cost too much	1	2	3	4	5

Section 6

The current recommended activity levels for adults are 150 minutes (2 ½ hours) of moderate intensity activity a week, in bouts of at least 10 minutes, or 75 minutes (1 ¼ hours) of vigorous intensity activity a week, plus strengthening activity on at least 2 days a week.

Moderate intensity activities will make you warmer and breathe harder, but you should still be able to carry on a conversation, e.g. brisk walking.

Vigorous intensity activities will make you warmer and breathe much harder, making it more difficult to carry on a conversation, e.g. running.

Examples of *strengthening activities* include exercising with weights and carrying or moving heavy loads such as groceries

Please indicate on the following scales the extent to which you think that meeting these recommended activity levels, *for you personally*, would be/is …

foolish	1	2	3	4	5	6	7	wise
unpleasant	1	2	3	4	5	6	7	pleasant
bad	1	2	3	4	5	6	7	good
unenjoyable	1	2	3	4	5	6	7	enjoyable
unnecessary	1	2	3	4	5	6	7	necessary

How much control do you have over whether you meet or exceed the recommended physical activity levels in the next month?

No control	1	2	3	4	5	6	7	Complete control

Please indicate the degree to which you agree with following statements.

	Strongly disagree						Strongly agree
Whether I do or don't meet or exceed the recommended physical activity levels in the next month is entirely up to me.	1	2	3	4	5	6	7
I intend to meet or exceed the recommended physical activity levels in the next month	1	2	3	4	5	6	7
I want to meet or exceed the recommended physical activity levels in the next month	1	2	3	4	5	6	7

The current recommendations for healthy eating, for adults, are to:

- eat at least 5 portions of fruit and vegetables a day
- eat plenty of starchy foods (potatoes, rice, pasta, bread etc.), ideally wholegrain varieties
- eat some dairy foods (milk yogurt, cheese etc.) every day, but only small amounts of high fat varieties
- eat some meat, fish, eggs or other non-dairy sources of protein every day, including 2 portions of fish a week (one of which should be oily fish)
- only eat a small amount of foods and drinks that are high in saturated fat and/or sugar
- limit salt intake to 6g (about a teaspoonful) per day

Please indicate on the following scales the extent to which you think that eating a healthy diet, *for you personally*, would be…

foolish	1	2	3	4	5	6	7	wise
unpleasant	1	2	3	4	5	6	7	pleasant
bad	1	2	3	4	5	6	7	good
unenjoyable	1	2	3	4	5	6	7	enjoyable
unnecessary	1	2	3	4	5	6	7	necessary

How much control do you have over whether you eat a healthy diet in the next month?

No control	1	2	3	4	5	6	7	Complete control

Please indicate the degree to which you agree with following statements.

	Strongly disagree						Strongly agree
Whether I do or don't eat a healthy diet in the next month is entirely up to me.	1	2	3	4	5	6	7
I intend to eat a healthy diet in the next month	1	2	3	4	5	6	7
I want to eat a healthy diet in the next month	1	2	3	4	5	6	7

Section 7

The following items reflect situations that are listed as common reasons for preventing individuals from participating in physical activities or, in some cases, dropping out. Using the scales below please indicate how confident you are that you could be physically active in the event that any of the following circumstances were to occur. Select the response that most closely matches your own, remembering that there are no right or wrong answers.

FOR EXAMPLE: In the first question if you have complete confidence that you could do physical activity even if "the weather was very bad," you would SELECT 100%. If however, you had no confidence at all that you could do physical activity (that is, confidence you would not do physical activity), you would SELECT 0%.

I believe that I could regularly be physically active over the next 3 months if…

	Not at all Confident				Moderately Confident					Highly Confident	
The weather was very bad (hot, humid, rainy, cold)	0	10	20	30	40	50	60	70	80	90	100
I was bored by the programme or activity	0	10	20	30	40	50	60	70	80	90	100
I was on holiday	0	10	20	30	40	50	60	70	80	90	100
I was not interested in the activity	0	10	20	30	40	50	60	70	80	90	100
I felt pain or discomfort when doing physical activity	0	10	20	30	40	50	60	70	80	90	100
I had to do physical activity alone	0	10	20	30	40	50	60	70	80	90	100
It was not fun or enjoyable	0	10	20	30	40	50	60	70	80	90	100
I believe that I could regularly be physically active over the next 3 months if…	**Not at all Confident**				**Moderately Confident**					**Highly Confident**	
It became difficult to get to the physical activity location	0	10	20	30	40	50	60	70	80	90	100
I didn't like the particular activity or programme that I was involved in	0	10	20	30	40	50	60	70	80	90	100
My schedule conflicted with my physical activity	0	10	20	30	40	50	60	70	80	90	100
I felt self-conscious about my appearance when I did physical activity	0	10	20	30	40	50	60	70	80	90	100

An instructor does not offer me any encouragement	0	10	20	30	40	50	60	70	80	90	100
I was under personal stress of some kind	0	10	20	30	40	50	60	70	80	90	100

The following items reflect situations that are listed as common reasons for preventing individuals from eating healthily.

Please indicate **how confident you would feel about eating healthy foods** under each of the following circumstances.

	Not at all confident		Neither		Very confident
When you are bored	1	2	3	4	5
When you are frustrated	1	2	3	4	5
When you are stressed	1	2	3	4	5
When you are lonely	1	2	3	4	5
When you are angry	1	2	3	4	5
When you are depressed	1	2	3	4	5
When you are anxious	1	2	3	4	5
When you are happy	1	2	3	4	5
When you are feeling good	1	2	3	4	5

Please indicate how confident you would feel about eating healthy foods under each of the following circumstances.

	Not at all confident		Neither		Very confident
While eating out at a restaurant with close friends	1	2	3	4	5
When only unhealthy foods are readily available	1	2	3	4	5
When you have to prepare healthy meals for yourself	1	2	3	4	5
When eating a healthy meal seems is just too much trouble	1	2	3	4	5
When eating a healthy meal means you have to cook it	1	2	3	4	5
When substituting a healthy for unhealthy food is a pain	1	2	3	4	5
When eating an unhealthy food is more convenient	1	2	3	4	5

When you are *grocery shopping*, how confident are you in your ability to:

Select whole grain bread or cereal in a grocery store	1	2	3	4	5
Select low fat dairy products (e.g. yogurt)	1	2	3	4	5
Select foods that are low in sodium (salt)	1	2	3	4	5
Select foods that are low in saturated fat	1	2	3	4	5
Select foods that are low in cholesterol	1	2	3	4	5
Select foods that are high in dietary fibre	1	2	3	4	5
Select foods that are low in or free of trans fats	1	2	3	4	5

Finally, in order for us to send you the booklet of health resources, please provide your name and address. These will be held in confidence, separated from your questionnaire responses (so that they remain anonymous) and only used for this study.

Name:

Address:

Postcode:

____

That's all of the questions, **thank you very much** for completing this first questionnaire!

Your booklet of health resources should reach you shortly, with instructions for the next part of the study.

If you have any questions, about the questionnaire you have just completed or the next parts of the study, please contact Lis at e.b.grey@bath.ac.uk or 01225 383589.

Appendix 4.4 Study 2 Time 2 questionnaire, additional section

N.B. This questionnaire was delivered online via Bristol Online Surveys

Section 1

Firstly, we would like to ask about the booklet we sent you.

1. Did you read the booklet? (Please select the most appropriate)

- ☐ No, I didn't read any of the booklet

    12. Please us why you did not read the booklet.

        I didn't have the time

        The booklet didn't look interesting

        Other

            12a. If you selected Other, please specify:

- ☐ I read some but not all of the booklet
- ☐ Yes, I read it all once
- ☐ Yes, I read it all and all or parts of it more than once

1a. If you only read some parts, which parts did you read?

1b. If you read some parts more than once, which parts did you read again?

2. In the past couple of weeks since reading the booklet, how often have you thought about the information in the booklet?

- ☐ Not at all
- ☐ Once or twice
- ☐ A few times only on the first few days after reading it
- ☐ A few times over the past weeks
- ☐ At some point on most days of the past weeks
- ☐ Every day

3. Has the information in the booklet made you think about the things you do in your own life?

- ☐ No, not at all
- ☐ A little bit, but it didn't seem relevant to me
- ☐ A little bit and it did seem relevant to me
- ☐ I thought about it a lot, but it didn't seem relevant to me
- ☐ I thought about it a lot and felt it was relevant to me

4. What were the main points you took from the booklet?

5. Did you talk about the booklet with friends or family?

Yes No

5a. If yes, what in or about the booklet did you discuss?

6. Please indicate on the following scales how *relevant* you thought the different bits of information in the booklet were *to you*.

	Completely irrelevant						Completely relevant
Information about the effects of physical activity on the body	1	2	3	4	5	6	7
Information about the role of muscle tissue in taking up sugar	1	2	3	4	5	6	7
Information about taste preferences	1	2	3	4	5	6	7
Information about fat tissue and leptin	1	2	3	4	5	6	7

7. Please rate the information in the booklet on the following scales.

Was the booklet …

… understandable?	Not at all understandable						Completely understandable
	1	2	3	4	5	6	7
… believable?	Not at all believable						Completely believable
	1	2	3	4	5	6	7
… enjoyable to read?	Not at all enjoyable						Very enjoyable
	1	2	3	4	5	6	7

8. Please comment if there were any parts of the booklet that you did not like or were hard to understand.

9. Have you thought about making any changes to your diet or activity levels as a result of the information in the booklet?

- [ ] Diet
- [ ] Both
- [ ] Activity levels
- [ ] Neither

10. Have you made any changes to your diet or activity levels as a result of the information?

- [ ] Diet
- [ ] Both
- [ ] Activity levels
- [ ] Neither

10a. If you have made changes, please tell us what these are:

10b. What in particular made you decide to make changes?

11. Did you stick the magnet up?

11a. If yes, please tell us where you stuck it and if you found it helpful.

Appendix 4.5 Study 2 Participant information sheet

Developing information resources to support healthy lifestyle change

Participant Information

Thank you for expressing an interest in our research study. This information document will tell you more about what taking part involves. Please take time to read it carefully and talk to others about the study if you wish.

If there are any points on which you are not clear please do ask a member of the research team (contact details are given at the end of these pages).

What is this study about?

We are developing some information resources to help people understand a bit more about their bodies and how the things we do in our lives affect our health. People can use this information to make healthy changes to their lifestyles.

In this study we are comparing two different booklets of resources - each person in the study will be randomly assigned to receive one or the other booklet. We will then look at how well each booklet works – do they help people to understand or think differently about their health? With your input we will be able to design better information resources that help more people.

Why have I been invited to take part?

You have been invited to take part because we are interested in the opinions of people who might find these resources helpful – people who are interested in their health and/or possibly thinking of making changes to their lifestyles to improve their health.

What will taking part involve?

This study has ***three*** parts for each participant to complete:

- ***Part 1 – an online questionnaire***
  We will send you a link, via email, to an online questionnaire that will ask for a few details about your current lifestyle as well as what you think about certain health issues. This should take about 30 minutes to complete.

- ***Part 2 – a nice new booklet of resources***

When you have completed the first questionnaire we will send you a booklet of information resources in the post. We are testing two different booklets of resources and you will be randomly assigned to receive one or the other. We would like you to read the booklet at least once but you will be able to choose when and how you do this – you may like to sit down for a quiet half hour and read it all at once, then look again just at the bits you found most interesting in the following days. Or you may prefer to read small sections at a time whenever you get a free 5 minutes. After one week we would like you to return the booklet to us – we will send you a pre-paid envelope to do this.

- ***Part 3 – a second online questionnaire***
  The final part of this study takes place two weeks after you have returned the booklet. We will send you an email link to another online questionnaire, asking what you think about certain health issues and the resources. This should take about 30 minutes to complete.

To thank you for taking part in this study, your name will be entered into a prize draw offering you the chance to win one of three prizes: **Amazon vouchers worth £100, £50 or £25.** To be entered into the draw you will need to complete all parts of the study. Winners will be picked at random when all participants have completed the study.

What are the potential risks to me in taking part?

We are not aware of any risks to you in taking part. However, if you feel uncomfortable at any point during the study, you will be free to withdraw without having to give a reason.

What are the potential advantages for me in taking part?

We hope that you will find the information in the resources interesting and useful. The results from this study will help us to make better information resources that will hopefully help people to lead healthier lives.

What will happen to the information that I provide?

When you have completed the study, all your questionnaire answers will be entered into a database that will not contain your name – so your data will be anonymous. The information you provide will be kept securely at the University of Bath for 5 years after the study has ended and will then be destroyed. Only members of the research team will have access to this information. Your name and email address will be kept in a separate database so that we can enter you into the prize draw.

What will happen if I don't want to carry on with the study?

If you change your mind about taking part in the study after completing the questionnaires, you will just need to contact Lis and she will destroy any information that you have already provided. You will be free to withdraw from the study at any point up until one week after you have completed the second questionnaire.

Who is organising and funding this study?

Developing the resources is Lis' PhD project, which is funded by the Evolution Education Trust.

Who has reviewed this study?

The Research Ethics Approval Committee for Health (REACH) at the University of Bath has reviewed and approved this study.

I'm interested in taking part but I want to find out more about the study first.

If you have any questions about the study or participation please do not hesitate to contact Lis or another member of the research team – their contact details are given at the end of this document. It is entirely up to you to decide whether or not you would like to take part.

I would like to take part, what do I need to do?

Lis will have sent you a link (via email) to the first questionnaire – just click on the link and start the survey. If the email has not arrived just let Lis know (her contact details are below) and she will help.

Thank you very much for taking the time to read this!

Contact details

Doctoral researcher	**Other members of the research team**	
Lis Grey	Professor Dylan Thompson	Dr Fiona Gillison
e.b.grey@bath.ac.uk	d.thompson@bath.ac.uk	f.b.gillison@bath.ac.uk
01225 383589	01225 383177	01225 384387

Appendix 5.1 Description of Evolife intervention in TIDieR format (Study 3)

TIDieR checklist item	Description	BCTs (Taxonomy v.1, 2013)
What		
- Researcher instruction and feedback	The researcher showed participants the Evolife website in an introduction session; the various information sections were pointed out with a brief explanation of the mismatch concept, then particular attention was paid to the goal setting section. The researcher provided advice on setting SMART goals, forming action plans, identifying barriers and forming coping plans. During the session, participants were asked to think of a behaviour (dietary or activity-related) they would like to change and this was used as an example when providing the goal setting and planning advice. If no example was offered by the participant, the researcher used an example from her own life. The researcher advised participants to try to visualise themselves enacting their plans when recording them on the website. The importance of continuing with a new behaviour for several weeks in order to form habits was emphasised. Participants were asked about their usual physical activity levels and the researcher prompted them to think about (and also offered advice on) ways they could increase their activity and overcome potential barriers. The researcher also showed participants how to use the pedometer (see below) to monitor their steps. Participants were also asked to complete a brief food frequency questionnaire during the session – this was used to provide personalised feedback (via email after the session)	Goal setting (behaviour) Action planning Problem solving (coping planning) Prompt mental rehearsal of successful performance Feedback on behaviour Prompt habit formation

		about changes they could make to improve their diet.	
-	Pedometer	Participants were provided with a Yamax EX210 digital pedometer that provided instant visual feedback to prompt self-monitoring of steps. The pedometers had a 7-day memory function, so participants needed to visit the Evolife website at least once a week in order to record (on the website goal setting area) their step counts before these were erased from the pedometer memory.	Feedback on behaviour Self-monitoring of behaviour
-	Evolife website	The intervention website ('Evolife') provided information about how physical activity and diet affect health, using the evolutionary mismatch concept as a unifying framework in which to present the information. The following sections were included: - Homepage: Personalised greeting and goal progress overview - Evolution and health: Overview of the mismatch concept and how this relates to health - Evolved to be active: information on how physical activity (or lack of) affects health, with focus on the role of muscle in metabolism; information on different forms of physical activity; tips on increasing activity; narrative to model how to increase activity in a busy life. - Shaped by food: information on how diet affects health, with focus on fat tissue; information on nutrient groups; tips on how to have a healthy diet; narrative to model changing dietary behaviour for weight loss. - My Evolife: information on setting SMART goals, action planning, barrier identification, coping planning, enlisting social support and changing the social environment; personalised page to record a daily step goal and 3	Information about health consequences Information about antecedents Demonstration of the behaviour Social support (practical and emotional) Prompt restructuring the social environment Goal setting (behaviour) Action planning Problem solving (coping planning) Self-monitoring of behaviour Feedback on behaviour Prompt habit formation

		other goals, along with plans for how to reach these goals in the coming week. Participants were encouraged to visit the site each week to record their progress towards each goal, this would then be displayed in a graph (for steps) and a traffic light table (green = goal reached, amber = goal partly reached, red = goal not reached). After saving their progress for the week, pop-up messages prompted participants to review, and change if necessary, their goals and/or plans for the coming week in order to overcome barriers and continue improving their health. Participants were encouraged to stick with a goal for several weeks at least to try to form habits.
Who provided	Health behaviour change researcher	
How	Individually delivered via the internet	
Where	One-off introduction session with researcher, either at the university or convenient public location. Then online delivery only.	
When and how much	12 week intervention. The introduction session lasted approximately 30 minutes. A one-off email providing dietary feedback was sent shortly after the introduction session (within 48 hours). Weekly reminders to visit the website, record progress, set goals and review information were sent via email for the first 6 weeks.	
Tailoring	Participants received personalised feedback on their diet and activity levels at the start of the intervention. The website provided a personalised display of participants' progress towards their goals.	

BCT = Behaviour change technique

Appendix 5.2 Evolife website text

[Home page]

Welcome to the EVOLIFE programme website!

This site has been designed to help you gain a better understanding of how the human body has evolved and what impact this has on your health today. Knowing why the body works in certain ways, and how different things in our lives affect our bodies, can help us to understand not just *what* things we need to do to be healthy but also *why* these things work. The programme is also designed to help you make manageable changes to your lifestyle and achieve better health.

How to use this site

In this website you'll find lots of information and advice, helpful suggestions of small, healthy changes that you can make, and guides to help you put these changes into action (and stick with them!). The My EVOlife section has areas where you can set your own healthy goals and record your progress.

You can navigate around the site using the tabs at the top or the links at the bottom of the pages. We would like you to visit the site at least once a week in order to record your progress towards your goals – regularly using the site in this way will help keep you on track. But otherwise, feel free to browse the site at your own pace and re-visit any pages, as you need, over the coming weeks.

[Evolution and health section home page – text accompanies a graphic timeline]

Evolution … and health?

Changes in the environment help to shape the human body, so it is useful to look at how our environment has changed over the years and see what has had the biggest impact on human lifestyles.

Hunter-gatherer

The very first humans separated from the ape family about 6 million years ago and many different species of human have existed since then. Modern humans (*Homo sapiens*) are the only surviving species and evolved from their ancestors about 200,000 years ago.

For most of humans' 6 million year history our ancestors survived by hunting, scavenging and gathering foods and lived in small groups that moved about the land.

Agricultural revolution

About 12,000 years ago, some humans started to grow plants from seeds they collected – they could then eat the plants that they grew. This was the start of farming, also known as the Agricultural Revolution. People came to depend more on the plants they grew and less on hunting and gathering for food. They also started to tame wild animals and were able to breed them for food. Farming gradually spread around the world and became the normal way of life for most of the population – it greatly affected the foods we ate and our daily activities.

Industrial revolution c.1800

The next big change to our environment was the Industrial Revolution, which happened only about 250 years ago. Machines were invented that were able to do the work of several humans, much faster and in larger quantities. They quickly became an everyday part of human lives – affecting everything from travel, to food and communication. The Industrial Revolution kick-started a great many changes to our environment and these have occurred in a relatively short time.

Digital revolution c.1950

Since the first digital computers were invented, about 60 years ago, the pace of change has become even faster, many tasks are now completely controlled by computers without the need for humans to lift a finger. Some people are calling our age – from the 1950s to present day - the Digital Revolution.

[Evolution health page 2]

The evolving human body

Adapting to our environments

The human body has been shaped over millions of years of evolution. Along the way our ancestors have lived in many different environments: facing ice ages and tropical heat waves, and eating a huge variety of foods depending on what was available.

When the environment changed - for example through climate warming and cooling or when humans travelled to new areas - the process of evolution gradually adapted the human body to better suit the new environment.

People with genes that made their bodies better able to survive and reproduce would pass their genes on to their children, the next generation, making them in turn more likely to survive and reproduce. These helpful genes that improved survival and reproduction are called adaptive genes.

Genes are instructions for the body; they tell the body how to develop, affecting many aspects of our lives, from what we look like to how our bodies function.

It’s a slow process…

With each new generation of humans, adaptive genes will be spread a bit further, but it usually takes several hundred generations (and so thousands of years) for adaptive genes to spread throughout a whole population.

For example, early humans were poorly adapted for walking on two legs as their spines and hips were still very 'ape-like'. Fossil records show how the human body gradually gained an s-shaped spine and large hips, which make us steadier on two feet. But this has taken over 6 million years!

Evolution isn't always *that* slow – humans only started to drink milk from other animals less than 10,000 years ago and at first very few adults were able to digest it. Now, a third of the world's population have the genes that allow their bodies to digest cows' milk. But this has still taken several hundred generations to adapt to one small change in our environment.

Quiz

Q. Changes in the environment help to shape the human body but changes to the body take a long time to occur - does this mean we will be better suited to things that have stayed the same in our environment or to things that have changed recently?

A. We will be better suited to things that have stayed the same in our environment *because the human body will have had longer to adapt to them.*

We are unlikely to be suited to things that have changed recently *because the human body won't have had time to adapt.*

[Evolution and health page 3]

What evolution means for us

A complete reversal

Although humans have lived in many different environments throughout our history, 2 important things stayed much the same for our ancestors:

- Physical activity was essential for everyday life
- Foods that were rich in energy (calories) were scarce

But recently our environment has changed a lot, and now these 2 things have completely reversed. Today it is possible to work and get food without moving much at all and energy-rich foods are widely available. The changes to our environment have happened too quickly for the human body to adapt. Conditions such as type 2 diabetes and cardiovascular diseases (e.g. high blood pressure, heart disease) can develop as our bodies struggle to cope with our lower levels of activity and larger amounts of calorie rich foods.

Our lifestyles have evolved too quickly for our genes to keep up → our bodies are struggling to cope with our modern way of life.

Coping with change

We don’t want to change our environment back to what it was thousands or even hundreds of years ago - and we probably wouldn’t be able to anyway. Many modern advances have been good for our health (and they certainly make things easier for us!). For example, we can quickly access safe, clean drinking water and immunisations have really lowered the spread of deadly diseases like measles.

These positive changes have led to the rise in life expectancy of humans – we are living longer than any of our ancestors have done before. However, although we’re living longer, more people are spending their later life in poor health and disability as diseases such as type 2 diabetes and cardiovascular disorder are becoming more common.

But we can make a few simple changes to our lifestyles – making our diets and physical activity levels slightly more like those of our ancestors – that will help keep us healthy for longer, so we can enjoy all the benefits of modern technology.

[Evolved to be active section home page]

How do our activities compare?

Click through to have a look at how our ancestors’ lifestyles compare with our own.
<interactive graphic>

Hunter-gatherer

Travel - Walking
Work - Building shelters
Housework - Making animal hide clothes
Getting food - Hunting, gathering, building fires, butchering animals

Early farmer

Travel - Walking
Work - Tending crops and animals
Housework - All cleaning and mending by hand
Getting food - Harvesting crops, milking cows, butchering livestock

Office worker (1900AD)

Travel - Mostly walking
Work - Mostly seated with some manual work
Housework - Most cleaning and mending by hand
Getting food - Walking to different shop daily, preparing most meals by hand

Office worker (today)

Travel - Mostly by car

Work - Mostly seated with little physical activity
Housework - Cleaning mostly done by machines or chemicals
Getting food - Drive to supermarket once a week or have shopping delivered, much preparation done by machine

[Evolved to be active section page 2]

Why do we need to be active?

Because physical activity has been such a necessary part of life for most of our ancestors, the human body has adapted to make use of physical activity

→ being active makes the body function better.

Although physical activity is often thought of as something to do if you want to lose weight or not get fat, it isn't just good for burning calories.

5 important good effects of being active

Building strong bones - in order to cope with physical activity our bodies make more bone cells. This is important as stronger, denser bones are less likely to break.

Improving flexibility – physical activity improves our flexibility by strengthening and lengthening the muscles around our joints. This helps us to move more easily and prevents injury.

Strengthening the heart – the heart is also made of muscle (cardiac muscle) and during physical activity this muscle has to work harder to pump blood around the body at a faster rate. In response to the extra work more cells develop to make the heart better able to cope. This helps to prevent heart disease.

Building strong muscles – physical activity causes the body to make more and bigger muscle cells. This is important because muscle cells are very good at taking sugar out of the blood, which prevents dangerously high blood sugar levels after a meal (one of the signs of type 2 diabetes). Strong muscles also improve our balance and reaction times, which helps prevent us falling over.

Improving mental health and mood – physical activity stimulates the brain to release endorphins, which are known to improve our mood. Being regularly active has been shown to improve self-confidence and reduce stress, anxiety and depression.

[Evolved to be active section page 3]

Goodbye muscles … hello sticky blood cells!

What happens to sugar in the blood normally?

Muscle tissue is very good at taking sugar out of the blood. This process is controlled by a hormone called insulin, which is made in the pancreas.

When we eat our blood sugar levels rise and our pancreas responds by releasing insulin in to the blood. Insulin tells the body's cells to remove sugar from the blood – the cells can then use the sugar for energy or store it.

With a healthy amount of muscle our blood sugar levels are easily controlled, keeping blood pressure down.

What happens when we don't have much muscle?

Fat tissue is not as good as muscle tissue at taking sugar from the blood, it needs a lot more insulin than muscle cells in order to take up the same amount of sugar.

If the sugar is not removed, it joins with things in the blood to make new particles that stick to and damage the blood vessel walls. This can make it harder for the blood to flow, increasing blood pressure.

Damaged blood vessels and high blood pressure can lead to heart disease and stroke if blood cannot get to the brain. The tiny vessels in the eyes and kidneys are particularly affected by this and if blood sugar levels remain high over a long period of time, blindness and kidney failure can occur.

<interactive graphic>

[Evolved to be active section page 4]

Evolved to… diabetes?

The importance of muscle

Throughout history, humans have had lots of muscle relative to fat tissue in their bodies. We have evolved to be able to make enough insulin (in our pancreas) for a fairly muscular body. However, in today's environment it is easy to lead very inactive lives and so have low amounts of muscle tissue in our bodies, and relatively higher proportions of fat tissue. This means we need more insulin to take up sugar from the blood quickly enough. **If muscle proportions become too low, the body simply cannot produce enough insulin** – when this occurs it is known as **type 2 diabetes**.

Becoming insensitive

Type 2 diabetes can also occur if the body's cells become less sensitive to insulin (i.e. when the insulin tells the cells to take up sugar, they don't). This is known as **insulin resistance** and it can also be caused by having too little muscle tissue. Because it will take longer to lower our blood sugar to a safe level after we eat if there is not enough muscle tissue, insulin levels in the blood will also remain high for longer, to keep telling the muscle and fat cells to take up sugar. If insulin levels remain high over a long period of time, cells can become less sensitive to it.

<interactive graphic>

Muscle and fat in proportion

Some fat tissue is essential. Our ancestors needed fat to keep them warm. However, we need a lot more muscle than fat in our bodies. An imbalance might occur if we have:

- Too much fat and normal muscle levels (obesity)
- Too little muscle but normal levels of fat (this person may look thin or 'normal' weight)
- Both too little muscle and too much fat (this person may look 'normal', overweight or obese).

The more muscle tissue we have, the more energy (calories) our bodies will burn, even at rest. So increasing our muscle mass, not only helps to control our blood sugar levels, but can also help to control our body size and weight.

[Evolved to be active section page 5]

Tips from our ancestors

We need to be a bit more active, like our ancestors were, in order for our bodies to be healthy. But this doesn't mean we need to totally give up technology or spend hours in the gym each week. Some people like to play sport or go to exercise classes and if you think they might work best for your life then get stuck in! But we can also make some everyday tasks a bit more active or try to rely a little less on technology. Here are some simple ideas to get you started:

Getting food

Our hunter-gatherer ancestors walked miles most days to gather food to eat … 60 years ago most people had to walk to and from several different shops to get their groceries …

… Today, we could park our cars in the farthest space of the supermarket car park and carry our bags rather than using the trolley to take them right to the car. We could walk to shops at the weekend when we have a bit more time or use a basket instead of a trolley if we are only getting a few things.

Work

Early farmers had to harvest their crops by hand … the first factory workers had to stand all day long and operate heavy machinery …

… Working in an office, using a computer all day, makes it hard to be active but we could try using every opportunity to get out of our seats. For example, going to talk to people in the same building instead of emailing them, making sure we don't just send one person to fetch the teas and coffees, and walking around when making phone calls. If you use a laptop, try putting it on a higher shelf so that you can stand up for a bit.

Housework

Our ancestors had to make, mend and wash their clothes by hand … before vacuum cleaners were invented people had to sweep and beat carpets …

… Actually housework today can give us quite a good ‘work out’ – we can carry the vacuum cleaner while using it (unless it is an upright model), make sure we really scrub the bath and tiles, and generally put in the ‘elbow grease’ rather than doing ‘a quick wipe round’. Not only will your body benefit but you’ll have a lovely clean house too!

These are just a few ideas – you might not like the sound of all of them but try thinking about your daily routine and other ways that you could make it a bit more active. Although these little changes might not sound like much on their own, if you make several little changes they will add up to have a significant effect on your health.

If you would like some more ideas on becoming more active, including free home workout plans, downloadable apps and links to groups and leisure centres in your area, try the NHS Choices’ Get Fit pages [hyperlink].

[Evolved to be active section page 6]

Interview with John

A couple of months ago, John had an NHS Health Check and was told he was at high risk of developing type 2 diabetes.

“I was quite shocked when the nurse showed me my results. I mean, I felt fine, just normal. I knew I was carrying a bit of extra weight – my ‘spare tyre’, the wife called it – but nothing major. I work long hours in an office and have to be at my computer all day. Then, because I live 30 miles away from where I work, I have to drive if I want to get home at a reasonable time. So it wasn’t that I didn’t want to be more active, it was just that going to the gym or whatever wasn’t really feasible.

And then when the nurse suggested looking at this information about evolution and health I thought ‘Oh here we go, the latest health fad and this time it sounds like they want me to go hunting deer for dinner or something!’ But it wasn’t like that at all. It made sense to me that the human body takes a long time to adapt to changes in the environment. And when I think what life was like when I was a lad and how different it is now, with all the computers and things, it’s clear to see that our environment is changing a lot, very quickly. I’d never really thought about what effect all this new technology was having on our bodies and seeing that, actually, we had evolved to rely on being active to help our bodies function was a bit of a surprise. I hadn’t realised that we need muscle to lower our blood sugar – I just thought exercise was for losing weight and keeping the heart ticking over. The website really made me see that, even though I was quite big, I probably didn't have much muscle.

So I decided to do something about it. I obviously couldn't cycle to work but I have started parking a few blocks away, giving me a 5 minute walk to the office. If I need to speak to someone in another part of the building I always get up and go to see them rather than phoning or emailing, like I used to. And I make sure that I get up from my desk at least once an hour, even if it's just to get a cuppa. It doesn't sound like much but all these little things add up. Before I would only go up and down the stairs at work once a day – to get to my office in the morning and then going home. But now, I'm up and down about 12 times a day to see people on different floors or to use the toilets on the floor below rather than the ones near my office. I even printed out a picture of a muscly hunter-gatherer and stuck it to my computer screen. That sounds a bit daft but it just helps remind me to think about my muscles! A few people at work did find it odd when I started coming to see them instead of phoning but I just joked that it was 'cause I wanted to see their lovely faces! Some guessed it was a fitness thing, which I got a bit of stick for, but actually most of them have started getting up more now too.

And I've just been back to the nurse and my risk score has gone down a bit. I've still got a way to go but I found that quite motivating – I've managed to make a difference to my health just by making a few small changes. So I'm going to try making a few more changes to really get my risk down. I also found it surprising how quickly climbing the stairs got easier – I never found it hard exactly before but now I can just take them 2 at a time without even thinking about it. And, I didn't expect this, but taking a quick break from my computer screen actually seems to help me concentrate – so I might even be more productive!"

[Shaped by food section home page]

Shaped by food

How do our diets compare?

Food is essential for the survival of all animals. For most of our ancestors, going right back to the apes, food was hard to get and not reliably available - in order to survive in these conditions, many different features evolved in the human body to help us get food and use its energy.

But recently our environment has changed a lot and now food is easy to get and reliably available; what's more, the foods that we eat today are often hugely different from what our ancestors ate, even 60 years ago.

<interactive graphic>

[Shaped by food section page 2]

Ancestral preferences

Why we evolved a sweet tooth (and a fatty one … and a salty one …)

Naturally sweet and fatty foods tend to be high in calories – they are said to be 'energy-rich' because a relatively small amount of these foods will provide a lot of energy. This was great for our ancestors, who used up a lot of energy just to gather food. So, gathering sweet and fatty foods helped our ancestors to survive better than gathering foods that were less energy-rich. Because of this humans have evolved to prefer sweet and fatty foods – generally we find them more tasty and pleasant to eat.

Salty foods were also hard for our ancestors to find. Salt provides an essential mineral (sodium) that our bodies need to function. Therefore humans developed a preference for salty foods - this helped make sure our ancestors got enough sodium.

Old preferences in a new environment

Today, food is readily available all year round and we tend to lead less active lifestyles, so we do not need as much energy as our ancestors. However, our evolved preferences for sweet and fatty foods still remain, prompting us to choose things like cakes and crisps instead of less energy-rich items. Unlike the naturally sweet and fatty foods that our ancestors had, many foods today tend to have been **processed** or refined in ways that remove vitamins, minerals and fibre. This makes the foods taste sweeter and require less chewing but it also means they only give us energy (calories) and little other goodness. Many foods today also have salt added to them – our preference for salty foods, when they are so easily available, causes us to eat too much of it.

Food and drink companies take advantage of our natural preferences and add sugar or sweeteners, salt and fats to their products to make them highly appealing.

How can our preferences lead to harm? <interactive graphic with text>

Malnutrition

The more artificially energy-rich foods we eat, the fewer nutritious foods we eat. This means that while we may get enough or too much energy, we do not get enough nutrients and vitamins, like protein, fibre and vitamin D.

Weight gain

The energy-rich nature of these foods means a very small portion can contain hundreds of calories – it is easy to consume a lot of calories from them without feeling full. This can lead us to put on weight. Being overweight means your heart constantly has to work harder to pump blood around a larger body – although exercise also makes the heart work hard, this is usually for short periods, allowing the heart to recover and strengthen in the rest periods. With a constant high weight, the heart is continuously working hard, which weakens it over time. Being overweight can also raise blood pressure, which weakens the blood vessels.

High blood sugar

Eating foods that contain a large amount of sugar will raise our blood sugar levels a lot. When this happens our bodies need to send insulin into the blood – insulin tells cells in our bodies to remove sugar from the blood. If we eat a lot of sugar over a long period (for example, by eating sugary foods every few hours) our bodies can struggle to produce enough insulin. This means that sugar will remain in the blood where it can join with other particles and stick to and damage blood vessel walls.

High blood pressure

The kidneys take unnecessary salt out of the blood and get rid of it in our urine. But in order to do this the salt needs to be diluted in the blood with water, so the body holds on to water. This results in a lot of liquid flowing through the blood vessels (the blood plus lots of salt and water molecules) – this increases blood pressure and weakens the vessels.

[Shaped by food section page 3]

Our fat friend

Fat for survival

The ability to store fat was essential for our ancestors' survival – they could not rely on food always being available when they needed it. For example, long periods with no rain could cause many of the plants and animals that hunter-gatherers ate to die. Early farmers were even more vulnerable because they became totally dependent on one source of food (their crops), which could be wiped out overnight in a flood. During these periods of famine they would have to break down their fat stores for energy. So, it was helpful if our ancestors were able to store any extra energy they got during seasons when lots of food was available. The more fat they could store, the more likely they would be to survive a famine. And if they survived they could pass on their genes for the ability to store lots of fat to the next generation.

Old genes that we can't fit into…

Today, we still have the genes that tell our bodies to store extra energy as fat. Our bodies are preparing us to survive a famine … but that famine never comes. In the UK, food is almost always available and easy to get hold of. Without using much energy we can prepare and eat lots of calorie-rich foods. This makes it easy to take in more energy than we need – and our bodies will store the extra energy as fat. Because we don't have to survive famine anymore the fat stores just keep building up and don't get broken down. Physical activity would also break the fat stores down, but many of us do not have very active lifestyles.

So, together our 'old' genes and 'new' environment lead us to gain fat, and we can become overweight or obese. The usual response to this is to go on a weight-loss diet (i.e. reduce our calorie intake). This is indeed a good idea but we need to remember that our bodies are still 'programmed' for a time when famines and low food intake threatened our survival. Our bodies have special systems to try to make sure we don't starve, and fat plays an important role in this system…

Understanding fat

All cells in the body will contain some fat – fat molecules are essential parts of cell membranes (the outer layer of a cell). This is why it is important to eat some fat. However, when we talk about body fat we often mean specific fat (adipose) tissue.

Adipose tissue is made up of adipocytes, which are cells that are great at storing fat. We all need a certain amount of adipose tissue as it helps to keep the body warm and protect our internal organs.

Obesity is not an excess of body weight (i.e. the weight of all our bones, organs, muscles etc.) but an excess of adipose tissue.

[Shaped by food section page 4]

Listening to our fat

The leptin letter

Adipose tissue doesn't just store fat: it also makes a substance called ***leptin***. Leptin acts a bit like a letter from the adipose tissue to the brain – it travels in the blood to be delivered to the brain. The leptin 'letter' tells the brain that we have fat stored. The more adipose tissue we have (i.e. the more fat is stored) the more leptin will be made. Depending on how much leptin there is, the brain will decide whether we need to eat more food or not and so make us feel hungry or full. If there is enough leptin the brain will stop us feeling hungry and if our leptin levels go down our brain will make us feel hungry so that we go looking for food.

For our ancestors this was a helpful way of making sure we would hunt for food when the body's energy stores were low – hunger would make our ancestors look for food. And it stopped us wasting energy by trying to get food when we didn't need it.

The problem is that if we regularly eat too much food and gain fat our brains alter their leptin level counters – the new higher level of leptin is set as 'normal'. Remember that, to our brains, stored fat is good as it will help us to survive. This part of the brain doesn't know that there is a supermarket just around the corner. When we lose even just a little bit of fat, and our leptin levels go down a bit, the brain thinks this is a threat to our survival and makes us feel hungry – so we eat more. This is a common problem that people face when trying to lose weight – after successfully losing a bit of fat their leptin levels fall and they feel very hungry. So they eat even more than usual and gain weight again.

How do we gain fat (adipose) tissue? <interactive graphic with text>

When we eat, the energy from our food can either flow in our blood to be used straight away or, if more energy is consumed than is immediately needed, the extra energy will be stored.

Some excess energy is stored in the liver but when the liver gets full any more energy is stored in adipose (fat) tissue.

And how do we lose it?
When we run out of the energy that was flowing in our blood – for example, a few hours after a meal - stored fat can be broken down and used.
Remember that our bodies need energy all the time to stay alive – even when we are asleep our hearts need to keep beating, our lungs keep breathing and our brains will keep working. This all requires energy. The more active we are the more energy our bodies will require.

What happens when we crash diet?

<interactive graphic>

[Shaped by food section page 5]

Tips from our ancestors

Working out what to eat

It would be impossible to start eating exactly what our hunter-gatherer ancestors did as the animals and plants available to them have evolved as well! It isn't necessary either – our different lifestyles mean that we will need different amounts and types of food. But we can look at the various diets of all our ancestors and see what kinds of foods our bodies are adapted to need and digest.

We have seen that our bodies are not well suited to diets high in sugar, fat and salt but we also know that humans need vitamins and minerals, certain fats, protein and fibre. So, we need to reduce our intake of very sugary, fatty and salty foods and make sure we get enough of the essential things.

Thinking about what kinds of foods were and weren't available to most of our ancestors can help us to make good food choices – generally the more natural and less processed or refined a food is, the better it will be.

Quiz <interactive graphic with text>

Question: It's breakfast time and you want something quick and easy. There's cornflakes, honey nut flakes, porridge, muesli or, of course, wholemeal or white toast. Which would be closer to what was available to our ancestors?

Answer: Porridge or muesli would both be good choices. The oats in porridge and muesli have been processed – to remove the husks and roll the grains – but a lot of the fibre remains intact and no sugar is added (unless you add it yourself!) The other cereals are shaped from highly processed grains, mixed with sugar and salt – the cornflakes would be better than the honey nut flakes though as they will contain less sugar. The bread for the toast is also made from highly processed grains, and many breads have sugar and salt added – wholemeal toast will contain more fibre than white though.

Back to basics

To help make sure we get enough of the things we need, it can be useful to understand a little about nutrients in food.

There are 3 macronutrients - carbohydrate, fat and protein – and they all provide our bodies with energy. Most foods will contain a mix of all 3 macronutrients in different proportions, but we tend to think of them as belonging to the group which they contain the most of – for example, bread contains mostly carbohydrate, so we think of it as a 'carb'. <interactive graphic with text>

Carbohydrate: These can be further divided into simple carbohydrates (sugars) and complex carbohydrates (starchy foods and fibre). Often a food will contain a mixture of types, for example wholegrain bread will contain some starch and some fibre, fruits and vegetables will contain some simple sugars and some fibre. More refined/processed foods are likely to contain less fibre and more simple carbohydrates. Note that when many people say 'carbs' they are often only referring to starchy carbohydrates. About 50% of our energy should come from carbohydrates – preferably vegetables, fruit and starchy sources. Remember that fibre will not provide any energy as it cannot be digested.

Fat: Fat provides double the energy (calories) per gram of food compared to carbohydrates or protein. This means that although 25 -35% of our energy intake should come from fat, the amount of fat in our diet will look less than the protein and carbohydrate. Fat can be divided into mono- and polyunsaturated, saturated and trans-fats. Trans fats should be avoided (they appear on labels as '(partially) hydrogenated' oil). Unsaturated fats are thought to be the healthiest - they help prevent heart disease by raising levels of good cholesterol and lowering bad cholesterol. Polyunsaturated fats are also known as 'essential' fats – we need to include these in our diet as the body cannot make them from other things we eat. Good sources of unsaturated fat are oily fish, avocados, nuts and seeds (like walnuts, linseed) and olive and rapeseed oils.

Protein: As well as providing energy, protein is essential for the growth and repair of cells – our cells are constantly dying and being replaced. The protein in meat, fish and eggs is the most easily absorbed by the body, but protein is also found in nuts, soya, dairy and pulses (beans and lentils). About 20 - 25% of our energy should come from protein.

Micronutrients: These are vitamins and minerals that are needed for many different functions in the body, such as carrying oxygen, maintaining the nervous system and protecting cells from damage. Generally, if we make sure we are getting a varied diet with lots of fruit and vegetables, some meat, fish, eggs, wholegrains, nuts and seeds then we will probably be getting all the micronutrients we need.

If you would like to know more about nutrition, try the British Nutrition Foundation's website [hyperlink]. It has lots of information on the different things in food, why they are needed and which foods are good sources of different nutrients.

Slimming down to fit our old genes

Not only are we built to hold on to extra energy as fat, our brains then work to stop us losing the fat, even though it has harmful effects on the rest of the body - it can seem like our bodies don't want us to lose weight!

Unfortunately we can't stop these responses, but being aware of why we feel hungry and recognising that this doesn't necessarily mean that we need more food can help us when we try to lose weight. We can try to ignore feelings of hunger and stick to planned meals, or try eating foods that make us feel fuller for longer – these are foods that are high in fibre, a substance found in plants.

Ultimately, **the only way to lose weight is to burn more energy (calories) than we take in** – so we can be more active to burn more energy, eat less or swap energy-rich foods to less calorific ones to reduce our energy intake, or do a bit of both.

Coping with cravings

When we crave a certain food or drink our sight and sense of smell are often taken up with the object we crave – either because the object is near us or we are imagining it. This makes us think even more about it and the craving gets stronger. If we can do something else that occupies our sight and sense of smell, this will mean they will not be taken up with the thing we crave. For example, studies have shown that imagining non-food related objects or scenes (like the smell of freshly mown grass) can overcome even strong cravings for chocolate, chips and other foods.

Doing something physical, like going for a brisk walk, can also take our minds off cravings – we have to think about the physical activity and this occupies our head instead.

Fundamentals of fibre

Humans cannot break down fibre very easily, indeed much of the fibre we eat passes through us undigested. So high fibre foods are a good choice to make us feel full without giving a lot of calories (but watch out for the other ingredients of meals or snacks that contain high fibre).

Good sources of fibre are:

- fruit and vegetables
- pulses, such as lentils, chickpeas and beans
- nuts and seeds
- whole grains

Most of these foods contain a mixture of insoluble and soluble fibre – and we need both. **Insoluble fibre** adds bulk to food, making us feel full and also helping food to move through the gut more easily. **Soluble fibre** turns into a gel in the stomach and helps to slow the absorption of food through the gut wall into the blood – this prevents the blood sugar levels rising rapidly to levels that, as the previous pages have shown, can be hard for the body to cope with.

It is best to increase the amount of fibre in your diet gradually – the body needs a little time to adjust to a change from a low-fibre to a high-fibre diet.

Here are some tips to help you get more fibre …

- Start the day with porridge or a high-fibre cereal topped with fruit and seeds
- Make wholegrain foods the rule and refined grains the exception – swap brown for white rice and choose wholemeal rather than white bread
- If you need to snack between meals, choose fruit, cut up fresh vegetables or unsalted nuts.
- Try adding lentils and beans to soups and stews
- Add extra vegetables when making pasta sauces, curries etc.

Ancestors and alcohol <interactive graphic with text>

Just like with highly processed energy-rich foods, the human body can process alcohol but only in moderate amounts. Alcohol has definitely been in the human diet for several thousand years - there is evidence of wine drinking from over 7000 years ago and, before modern water treatment systems were invented, the weak alcoholic drinks available were safer to drink than the unclean water. But we still have not evolved the genes to fully process alcohol – this is seen in the heart, liver and mental diseases that result from heavy or long-term drinking.

Some research has found that small amounts of alcohol can have beneficial effects on the heart – but this means one or two glasses per day. How you drink also seems to be important. Having 7 drinks on a Friday night and then not drinking for the rest of the week is not the same as having one drink a day. Drinking a lot on one day is bad for your health, whereas spreading out the 7 drinks over at least 3 days might be beneficial.

If you want to cut down your drinking, you could try alternating alcoholic drinks with water – this will fill you up in the way that fibre-rich foods do for hunger (it's best not to alternate with soft drinks as these are often full of sugar). Or you could try opting for smaller size drinks or ones with a lower strength (ABV %, which should be marked on the label). If you would like more help and advice to cut down on alcohol try the NHS One You website

[Shaped by food section page 6]

Interview with Cathy

Cathy had her NHS Health Check 6 months ago and was told she was at high risk for developing type 2 diabetes and cardiovascular disease.

"I was annoyed, more than anything, when the GP told me my risk score. My weight has been something I've battled with for years and I've tried just about every diet going. The last time I managed to lose weight was for my daughter's wedding a year ago – I really wanted to look my best for the photos and I did drop 3 stone. But I was following this miserable diet with none of the foods I like and seemed to constantly feel hungry. So after the wedding I didn't stick to it and the weight just crept back on. Saying that though, it's not like I ate a lot of burgers and chips or something – I always tried to have the lower fat or sugar free options to keep down the calories. So this risk score was just sort of rubbing salt in the wound.

And when the doctor suggested looking at this information on evolution and health I felt like saying 'What's the point? It'll just be about another stupid diet that I can't stick to.' But, out of curiosity I suppose, I did have a look at the site and it wasn't what I was expecting at all. I'd never thought about why we feel hungry or like sweet things before but it made sense that these reactions would have helped our ancestors survive. And it felt like a light had been turned on to realise that, actually, just because I was feeling hungry or craved a chocolate biscuit didn't mean I was weak-willed or lacked determination – they were natural responses.

Comparing the foods I was eating with what our ancestors ate was helpful – I could see that the low calorie snack bars and biscuits weren't filling like the fibrous foods our bodies were adapted to. And although I thought I was being really good at sticking to small portions at meal times, most of the meals I made were low fibre too and often didn't have much protein, so I'd soon feel hungry again. But I've made some changes now, trying to include more fibre and protein in my meals with nuts, beans, fish and lots of vegetables. I have slightly bigger portions now but I don't think they're high in calories, because most of the bulk comes from the beans and veg. This helps to fill me up for longer. When I'm in the supermarket or a café looking at different foods, I try to ask myself 'Is this anything like what my ancestors would have eaten?' And if it isn't, say the ingredients list includes a load of 'modified' things, 'stabilisers' and funny chemicals, or it's obvious there's a load of sugar in it, then I won't have it.

My husband wasn't exactly supportive at first as he thought it would just be another fad diet that I'd try for a couple of weeks. And we have had a bit of trial and error with the high fibre foods – we've established that neither of us is keen on lentils. I do still get hungry between meals sometimes too and I'm afraid I have a bit of a sweet tooth so it's hard not to reach for biscuits at these times, even though I try to make sure there are always fruits or nuts for healthier snacks.

But on the whole it's going well. Filling meals and few snacks is just part of the routine now. I don't feel like I'm following 'a diet' and I've actually found some interesting new foods through trying out higher fibre recipes. I still have a night out with the girls occasionally, when I don't worry about sugar contents or fibre and I think that's fine once in a while. Most importantly, my risk score has gone down and I've lost a bit of weight – nothing drastic but I've managed to keep it off. That's boosted my confidence a bit and it feels good to fit into a smaller dress size."

[My evolife section home page]

My evolife

This section is to help you make some changes to your lifestyle – making it slightly more like our ancestors' – to improve your health.

We don't need to go back to living like cave men but it's important to bear in mind that for most of human history:

- Physical activity was essential for everyday life
- Foods that were rich in energy (calories) were scarce

So if we can increase our activity levels and make sure our diets are not full of highly processed, high calorie food we'll be well on the way to a healthier life.

Making changes isn't always easy but there are some tried and trusted things we can do to improve our chances of making and maintaining changes and this section will guide you through them…

[My evolife section page 2]

Planning your evolife

The main aim of the evolife programme is to help you achieve better health for the long term. But that's quite a broad aim and there are many ways to reach it. When we try to achieve something, we are more likely to be successful if we make a plan and set short term goals to reach on the way to our aim. This can turn a vague and seemingly mammoth task into something manageable, which helps with motivation.

SMART goals

Goals are not all equal – the best goals are SMART goals. SMART stands for Specific, Measurable, Achievable, Relevant and Time-bound. These are 5 factors that we need to consider when setting short term goals on the way to our main aim of good health.

Specific

The more specific a goal the better as it helps us to stay focused and avoid putting off changing our behaviour.

Poor goal: 'to walk more' – this is too broad, it would be easy to push the goal aside and pass up an opportunity to, say, walk to the shop at lunch time by thinking 'oh I'll walk more this evening instead.'

Better goal: 'to walk for at least 20 minutes around the park or to the shop every lunch time during the week, and for half an hour on Saturday and Sunday mornings after breakfast along the river'. This goal specified what you will do, when you will do it and where. You could also specify any other people you will do it with.

Measurable

If we can measure our progress we are more likely to stay on track.

Poor goal: 'to eat more healthily' – this could be measured in many different ways.

Better goal: 'to reduce the amount of sugar and increase the amount of fruit and vegetables I eat by replacing my afternoon biscuit with a piece of fruit or carrot sticks'. It would be easy to tell if you did this each day.

Achievable

We need to be honest with ourselves – setting too ambitious a goal and failing to achieve it will only de-motivate you. That's not to say we shouldn't push ourselves a bit but it is better to set a series of smaller, more reachable goals that will help us build confidence in order to achieve our aim. What is achievable will be different for each individual.

When thinking about what is achievable for you it might help to consider all your current commitments, your current abilities and any previous attempts you have made to change your lifestyle. What is achievable will also change with time, for example as your fitness improves you will be able to, say, walk for longer periods. This makes it important to update your goals regularly.

Relevant

A goal needs to be for something that you value and see as relevant – choose something that you enjoy or really feel will be useful to you in some way. This will help you to stick at it and make long-term changes that you are happy to maintain. When setting goals it really is worth thinking about what is important to you and it sometimes helps to record this alongside your goal.

For example, many people have a vague wish to be healthier but what actually helps them to make changes is something more personal, like wanting to be able to play with their children without getting out of breath. The reasons behind your goals don't have to make sense to anyone else, what matters is that they are important to you.

Time-bound

For a short-term goal it is important to set a target date for completion – this helps us to check our progress and gives us something to aim for, which helps with motivation. If we don't set a target date it is very easy to keep putting things off, and then we never achieve our goals. Weekly progress checks are a good way to start and longer term aims can be broken down into weekly goals.

For example, if you aimed to lose 5kg by, say, your next summer holiday (5 months away) then setting goals to lose about a quarter of a kilo a week gives you manageable targets to keep you focused and motivated. In this case you would also need to specify how you are going to lose weight – will you limit your food intake or increase your activity or both?

[My evolife section page 3]

Maintaining your evolife

Checking progress

Making sure the goals you set are SMART will help to keep you motivated and focused. But it's also important to keep checking your progress – looking back at what we have achieved tends to make us feel more positive and able to maintain our new behaviour or challenge ourselves a little further. Looking back at what our goals are can help keep us motivated too.

Planning against problems

Taking time to think about our progress can also help us to identify potential problems – is anything making reaching a goal particularly difficult? Not meeting our goals doesn't make us failures – we just need to learn from the experience and make plans to overcome barriers. A useful technique to try is the IF-THEN plan - IF x happens, THEN I will …

For example, you may have made a plan to make your own, healthier, curry from scratch instead of getting a takeaway. You had found a recipe and written out the ingredient list but when you get to the supermarket it has sold out of all many of the things you need. On a frantic dash round a busy supermarket, this can be enough to throw you off course and you end up getting a takeaway or ready meal anyway. Having a back-up 'then' plan for an alternative home-made meal can help – in this case you might have an alternative curry recipe that uses different ingredients.

Here's another example, showing how to record an IF-THEN plan:

IF I have to work late and miss my Pilates class at the gym, THEN I will vacuum the house as soon as I get home and do 10 minutes of Pilates in the living room on my own before dinner, to get some exercise.

An evolife, for life

A healthy lifestyle needs to be maintained for the long term, so it is also worth keeping track of how much you enjoy any changes you make. If you really don't like them it's unlikely you'll keep them up - it would be better to think of an alternative.

That said, new activities or diets need to be given a fair chance, so try to stick with them for a few weeks. If you increase your activity levels, your muscles may feel a bit sore at first but this will improve as you get fitter.

Over time, your healthy behaviours will become easier, you'll form new habits and your ability to resist old temptations will grow.

Also bear in mind that our environment is constantly changing, so be prepared to adapt in future months or years. For example, if you change jobs or move to a smaller house, this may affect your ability to get to a gym class or reduce the amount of activity you can get from housework. You can use the same techniques you've used here to set new goals and build new habits.

[My evolife section page 4]

The social group and you

Humans are social creatures – living in groups has been key to our survival as a species. It's important to remember the role that other people can play when we are trying to make healthy changes to our lifestyles.

Our friends, family and colleagues can provide excellent support and encouragement when we are trying to change our behaviour – it can even be helpful (and fun!) to make changes together.

But other people can also make it hard for us to change by encouraging us to keep unhealthy habits or complaining when we try something new. Especially if our old habits are things we did with other people - like always getting fish and chips and several beers with colleagues on a Friday night - it can be hard to change when they don't want to.

Sometimes, other people can think they are being helpful by reminding us to stick to our new activities or not eat unhealthy foods, but actually this just turns into nagging, which tends to cause the behaviour it's designed to stop!

An especially tricky situation to handle is when our friends and family try to be kind by, say, offering second helpings or telling us we don't need to lose weight or go to the gym. It can be hard to stick to your goals if you are worried about offending people.

However, there are some things we can do to manage different social pressures...

Managing social pressures <interactive graphic with text>

> Try to avoid tempting situations or make them slightly healthier
>
> For example, if you know you tend to meet friends in cafes but find it hard to resist the cakes, you could try suggesting going somewhere else like the park, a gallery or just shopping. If you do go to restaurants, be the first to order and go for healthy foods - this is much easier than waiting until after others order high-calorie foods.
>
> Think up responses in advance and practise them
>
> In the heat of the moment it's very easy to follow old habits and, for example, accept your mother's offer of second helpings. Knowing how you are going to refuse tempting offers makes it easier to do, so try thinking about exactly what you are going to say and practise it out loud (sounds silly but it helps!). Some good examples are "It looks delicious but I actually had quite a big breakfast and I'm still quite full" or "I had a big serving first time – it was great but I couldn't fit any more in!"
>
> Tell people about your effort to change, explain why it is important and ask them to help
>
> Many people love helping others, so if you tell them that you are trying to be more active or eat more healthily – and explain why it is important to you – they are likely to want to help or at least not hold you back. This will also help them understand any changes in your behaviour, which can make it easier for them to accept changes that affect them. Giving people specific ideas of how they could help you can make them feel useful – for example,

you could ask a friend if they would come with you to a new gym class for the first time, or ask your partner not to nag you.

Be willing to compromise if changes affect others (e.g. family meals or routines)

For example, if you want to be more active in the evenings but still see your family and they all want to watch TV then, you could try doing 'ad break challenges' – competing to do the most star jumps, say, while the adverts are on.

Don't expect people to adjust instantly – it takes time to change habits, for them and you. But if you can stick to your guns and repeat your healthy behaviour over and over again, then you and your friends and family will build new, healthier habits.

[My evolife section page 5]

Keeping track

Hi [name]

This is where you can set some healthy living goals and track your progress over time. Make sure you've read Planning your evolife, which will help you understand how to make realistic goals and achieve them.

We will send you weekly emails to remind you to log your progress and review your goals – you may need to adjust your goals slightly and this can be done once a week if necessary.

<overview table>

Goals

There is space here to set up to four different goals and we would like one of these to be a daily step goal – you can use the pedometer to track your steps and record them on this site to monitor your progress. You can choose what you would like the other three goals to be – you might like to have some for diet and some for activity.

Step goal

For the first week, we recommend that you just record your normal step count, without setting goals or trying to change your activity levels. This will give you a starting point for setting your goal in the second week.

10,000 steps per day is recommended as a good minimum to help maintain a healthy body. Hint: Ten minutes of brisk walking is about 1,000 steps.

Daily step target:

Goal 1

My goal for this week:

How I plan to meet my goal:

Goal 2

My goal for this week:

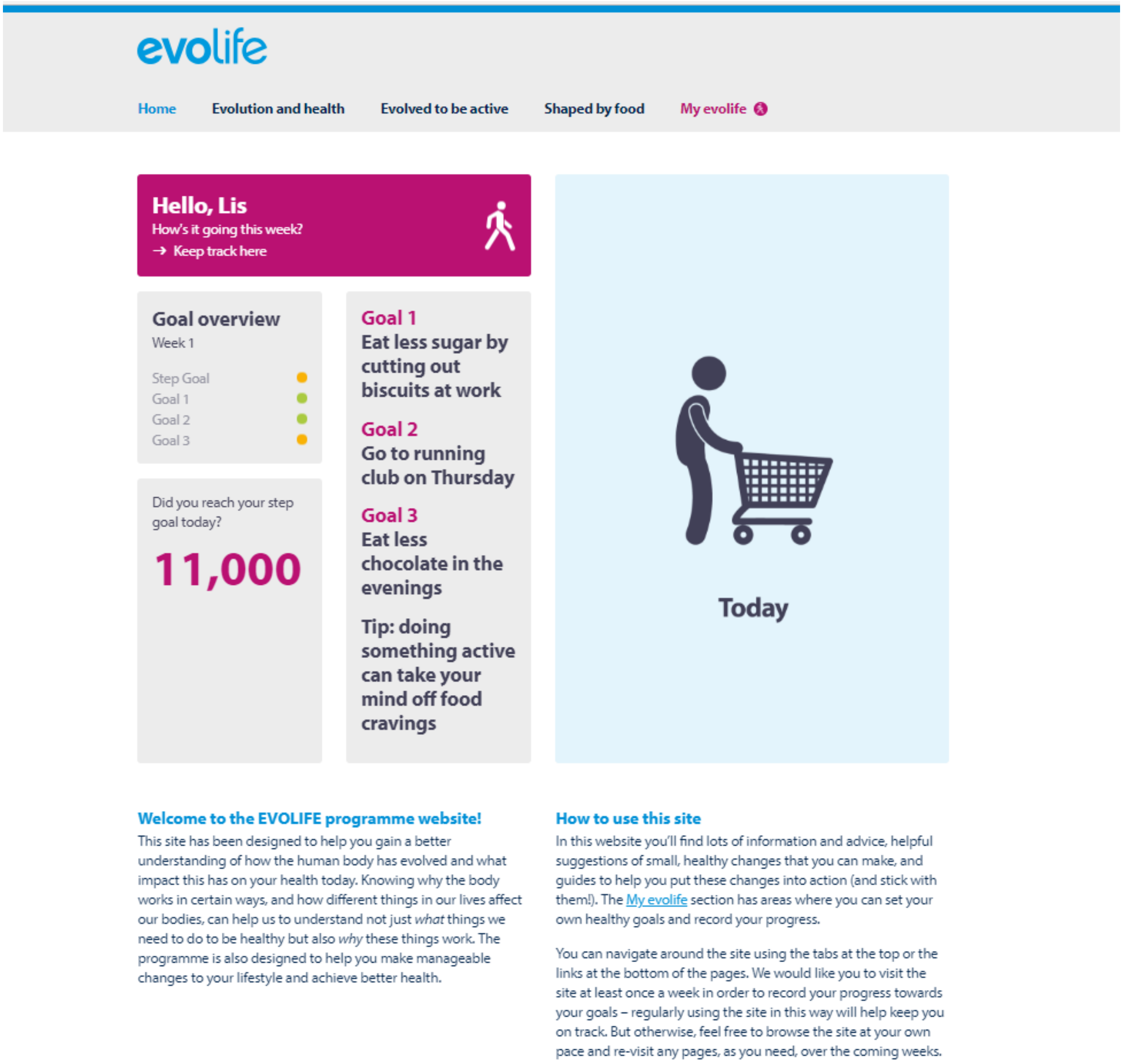
How I plan to meet my goal:

Goal 3

My goal for this week:

How I plan to meet my goal:

Appendix 5.3 Example pages from the Evolife website



What evolution means for us

A complete reversal

Although humans have lived in many different environments throughout our history, two important things stayed much the same for our ancestors:

- Physical activity was essential for everyday life
- Foods that were rich in energy (calories) were scarce

But recently our environment has changed a lot, and now these two things have completely reversed. Today it is possible to work and get food without moving much at all and energy-rich foods are widely available. **The changes to our environment have happened too quickly for the human body to adapt.** Conditions such as type 2 diabetes and cardiovascular diseases (e.g. high blood pressure, heart disease) can develop as our bodies struggle to cope with our lower levels of activity and larger amounts of calorie rich foods.

Our lifestyles have evolved too quickly for our genes to keep up – our bodies are struggling to cope with our modern way of life.

Coping with change

We don't want to change our environment back to what it was thousands or even hundreds of years ago - and we probably wouldn't be able to anyway. Many modern advances have been good for our health (and they certainly make things easier for us!). For example, we can quickly access safe, clean drinking water and

evolife

Home | Evolution and health | Evolved to be active | Shaped by food | My evolife

Why do we need to be active? | Goodbye muscles... | Evolved to... diabetes? | Tips from our ancestors | Interview with John

How do our activities compare?

Click through to have a look at how our ancestors' lifestyles compare with our own.

Hunter-gatherer

Before Agricultural Revolution

Before 10,000 BC

Exercises Heart

Improves flexibility

Builds Muscle

Strengthens Bones

Travel	Walking
Work	Building shelters
Housework	Making animal hide clothes
Getting food	Hunting, gathering, building fires, butchering animals

Hunter-gatherer | Early farmer | Office worker | Office worker - today

evolife

Home | Evolution and health | Evolved to be active | Shaped by food | My evolife

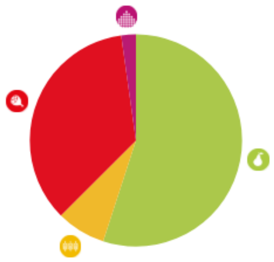
Ancestral preferences | Our fat friend | Listening to our fat | Tips from our ancestors | Interview with Cathy

Shaped by food

How do our diets compare?

Food is essential for the survival of all animals. For most of our ancestors, going right back to the apes, food was hard to get and not reliably available - in order to survive in these conditions, many different features evolved in the human body to help us get food and use its energy.

But recently our environment has changed a lot and now food is easy to get and reliably available. What's more, the foods that we eat today are often hugely different from the foods that our ancestors ate, even just 60 years ago.



20,000 years ago | Today

Find out more on Shaped by food...

Ancestral preferences | Our fat friend | Listening to our fat | Tips from our ancestors

evolife

Home | Evolution and health | Evolved to be active | Shaped by food | My evolife

Planning your evolife | Maintaining your evolife | The social group and you | Keeping track | Log out

Planning your evolife

The main aim of the **evolife** programme is to help you achieve better health for the long term. But that's quite a broad aim and there are many ways to reach it. When we try to achieve something, we are more likely to be successful if we make a plan and set short term goals to reach on the way to our aim. This can turn a vague and seemingly mammoth task into something manageable, which helps with motivation.

SMART goals

Goals are not all equal – the best goals are SMART goals. SMART stands for **Specific**, **Measurable**, **Achievable**, **Relevant** and **Time-bound**. These are 5 factors that we need to consider when setting short term goals on the way to our main aim of good health.

Specific

The more specific a goal the better as it helps us to stay focused and avoid putting off changing our behaviour.

Poor goal: 'to walk more' – this is too broad, it would be easy to push the goal aside and pass up an opportunity to, say, walk to the shop at lunch time by thinking 'oh I'll walk more this evening instead.'

Better goal: 'to walk for at least 20 minutes around the park or to the shop every lunch time during the week, and for half an hour on Saturday and Sunday mornings after breakfast along the river'. This goal specified *what* you will do, *when* you will do it and *where*. You could also specify any other people you will do it with.

Home | Evolution and health | Evolved to be active | Shaped by food | My evolife

Planning your evolife | Maintaining your evolife | The social group and you | Keeping track | Log out

Hi Lis

Keeping track

This is where you can set some healthy living goals and track your progress over time. Make sure you've read Planning your evolife, which will help you understand how to make realistic goals and achieve them.

We will send you weekly emails to remind you to log your progress and review your goals – you may need to adjust your goals slightly and this can be done once a week if necessary.

Overview

Goals

There is space here to set up to four different goals and we would like one of these to be a daily step goal – you can use the pedometer to track your steps and record them on this site to monitor your progress. You can choose what you would like the other three goals to be – you might like to have some for diet and some for activity.

Week | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | **35** | 36

Step goal

For the first week, we recommend that you just record your normal step count, without setting goals or trying to change your activity levels. This will give you a starting point for setting your goal in the second week.

10,000 steps per day is recommended as a good minimum to help maintain a healthy body. Hint: Ten minutes of brisk walking is about 1,000 steps.

Step Goal

Daily Step Target

500 ▼

Save

Appendix 5.4 Study 3 baseline questionnaire

Trial of a new online programme for physical activity and healthy eating.

Questionnaire pack

This questionnaire is made up of several sections with questions that have been designed to give us an idea about your current lifestyle and what you think about certain issues to do with healthy living.

There are **no trick questions**. We simply want to know **your personal feelings and beliefs**.

Please read the instructions for each question carefully and respond to all items. If you have any questions whilst filling it out please ask the researcher.

This questionnaire should take about **20 minutes** to complete.

Participant Code ___________________ DATE _____ /_____ /_____
[*To be completed by researcher*]

Firstly, please provide us with a little background information about you.

1. Gender: Male ☐ Female ☐

2. Age: __________

3. What is your ethnic group?

White	☐	Black/Black British	☐
Asian/British Asian	☐	Mixed	☐
Other	☐		

3 a. If you selected 'Other', please specify:

4. What is your marital status?

Single	☐	Stable relationship (unmarried)	☐
Married/civil partnership	☐	Divorced/separated	☐
Widowed/widower	☐		

5. What is your employment status?

Employed/self-employed (full-time)	☐	Employed/self-employed (part-time)	☐
Student	☐	Retired	☐
Unemployed (looking for work)	☐	Unemployed (not looking for work)	☐
Unable to work	☐	Prefer not to say	☐

6. What is your highest educational qualification?

No formal qualifications	☐	GCSE/O level or equivalent	☐
A level/NVQ level 3 or equivalent	☐	HNC/HND/dipHE or equivalent	☐
Bachelors degree	☐	Masters/postgraduate qualification	☐
Doctorate/advanced professional qualification	☐		

7. Do you or you have you ever smoked?

☐ Never smoked

☐ Currently smoke

Please state average number of cigarettes per day ___________________

☐ Used to smoke

Please state when you quit smoking __________________________________

8. Have any of your blood relations (e.g. mother, brother) ever been diagnosed with

Heart disease? **Yes** ☐ **No** ☐

Type 2 diabetes? **Yes** ☐ **No** ☐

9. Are you currently taking any medications? If yes, please let us know the name and dose of each medicine you take as well as stating how long you have been taking it.

Medication:

Dose (e.g. 1 x 20mg twice a day):

When started:

Medication:

Dose (e.g. 1 x 20mg twice a day):

When started:

Medication:

Dose (e.g. 1 x 20mg twice a day):

When started:

If more space is needed please use the back page of this questionnaire.

10. Have you previously received any support or tried any programmes/apps to help you change your lifestyle? (e.g. WeightWatchers, an exercise on referral scheme)

If so, please state what support/programmes and when this was.

11. We would like to know how good or bad you believe your health is today.

Please indicate how good or bad you believe your health is TODAY on the following scale.

This scale is numbered from 0 to 100.

100 means the best health you can imagine.

0 means the worst health you can imagine.

Mark an X on the scale to indicate how your health is TODAY.

The worst health you can imagine	0 ——————— 50 ——————— 100	The best health you can imagine

Now, please write the number you marked on the scale.

Your health today: ______________

By placing a TICK in one box in each group below, please indicate which statement best describes your own health state today.

Do not tick more than one box in each group.

12. Mobility

I have no problems in walking about ☐

I have some problems in walking about ☐

I am confined to bed ☐

13. Self-care

I have no problems with self-care ☐

I have some problems washing and dressing myself ☐

I am unable to wash and dress myself ☐

14. Usual activities (e.g. work, study, housework, family or leisure activities)

I have no problems with performing my usual activities ☐

I have some problems with performing my usual activities ☐

I am unable to perform my usual activities ☐

15. Pain/discomfort

I have no pain or discomfort ☐

☐

I have moderate pain or discomfort

I have extreme pain or discomfort ☐

16. Anxiety/depression

I am not anxious or depressed ☐

I am moderately anxious or depressed ☐

I am extremely anxious or depressed ☐

17. We are interested in the reasons underlying peoples' decisions to engage or not engage in physical activity.
Using the scale below, please indicate to what extent each of the following items is true for you.

	Not true for me		**Sometimes true for me**		**Very true for me**
a. It's important to me to be active regularly	0	1	2	3	4
b. I don't see why I should have to be active	0	1	2	3	4
c. I am active because it's fun	0	1	2	3	4
d. I feel guilty when I'm not active	0	1	2	3	4
e. I'm active because it is consistent with my life goals	0	1	2	3	4
f. I'm active because other people say I should be	0	1	2	3	4
g. I value the benefits of physical activity	0	1	2	3	4
h. I can't see why I should bother being active	0	1	2	3	4
i. I enjoy my physical activity sessions	0	1	2	3	4
j. I feel ashamed when I miss an activity session	0	1	2	3	4
k. I consider physical activity part of my identity	0	1	2	3	4
l. I take part in physical activity because my friends/family/partner say I should	0	1	2	3	4
m. I think it is important to make the effort to be active regularly	0	1	2	3	4
n. I don't see the point in physical activity	0	1	2	3	4
o. I find physical activity pleasurable	0	1	2	3	4
p. I feel like a failure when I haven't been physically active in a while	0	1	2	3	4
q. I consider physical activity a fundamental part of who I am	0	1	2	3	4
r. I engage in physical activity because others will not be pleased with me if I don't	0	1	2	3	4
s. I get restless if I don't engage in physical activity regularly	0	1	2	3	4
t. I think physical activity is a waste of time	0	1	2	3	4
u. I get pleasure and satisfaction from participating in physical activity	0	1	2	3	4

	Not true for me		Sometimes true for me		Very true for me
v. I would feel bad about myself if I was not making time to engage in physical activity	0	1	2	3	4
w. I consider physical activity consistent with my values	0	1	2	3	4
x. I feel under pressure from my friends/family to be physically active	0	1	2	3	4

18. We are interested in the reasons underlying peoples' **decisions to eat the way they do**.

Using the scale below, please indicate **to what extent each of the following items is true for you**.

	Not true for me		Sometimes true for me		Very true for me
a. It's important to me to eat healthily	0	1	2	3	4
b. I don't see why I should have to eat healthily	0	1	2	3	4
c. I eat healthily because it's fun	0	1	2	3	4
d. I feel guilty when I do not eat healthily	0	1	2	3	4
e. I eat healthily because it is consistent with my life goals	0	1	2	3	4
f. I eat healthily because other people say I should	0	1	2	3	4
g. I value the benefits of eating healthily	0	1	2	3	4
h. I can't see why I should bother eating healthily	0	1	2	3	4
i. I enjoy eating healthy meals	0	1	2	3	4
j. I feel ashamed when I eat unhealthy meals or snacks	0	1	2	3	4
k. I consider eating healthily part of my identity	0	1	2	3	4
l. I eat healthily because my friends/family/partner say I should	0	1	2	3	4
m. I think it is important to make the effort to eat healthily	0	1	2	3	4
n. I don't see the point in eating healthily	0	1	2	3	4
o. I find eating healthily pleasurable	0	1	2	3	4
p. I feel like a failure when I haven't eaten healthily in a while	0	1	2	3	4
q. I consider eating healthily a fundamental part of who I am	0	1	2	3	4
r. I eat healthily because others will not be pleased with me if I don't	0	1	2	3	4
s. I get uncomfortable or frustrated if I don't eat healthily regularly	0	1	2	3	4
t. I think eating healthily is a waste of time	0	1	2	3	4
u. I get pleasure and satisfaction from eating healthily	0	1	2	3	4
v. I would feel bad about myself if I was not making time to eat healthily	0	1	2	3	4
w. I consider healthy eating to be consistent with my values	0	1	2	3	4
x. I feel under pressure from my friends/family to eat healthily	0	1	2	3	4

The following items reflect situations that are listed as common reasons for preventing individuals from participating in physical activities or, in some cases, dropping out. Using the scales below please indicate how confident you are that you could be physically active in the event that any of the following circumstances were to occur. Select the response that most closely matches your own, remembering that there are no right or wrong answers.

FOR EXAMPLE: In the first question if you have complete confidence that you could do physical activity even if "the weather was very bad," you would SELECT 100%. If however, you had no confidence at all that you could do physical activity (that is, confidence you would not do physical activity), you would SELECT 0%.

19. I believe that I could regularly be physically active over the next 3 months if…	**Not at all Confident**					**Moderately Confident**					**Highly Confident**
a. The weather was very bad (hot, humid, rainy, cold)	0	10	20	30	40	50	60	70	80	90	100
b. I was bored by the programme or activity	0	10	20	30	40	50	60	70	80	90	100
c. I was on holiday	0	10	20	30	40	50	60	70	80	90	100
d. I was not interested in the activity	0	10	20	30	40	50	60	70	80	90	100
e. I felt pain or discomfort when doing physical activity	0	10	20	30	40	50	60	70	80	90	100
f. I had to do physical activity alone	0	10	20	30	40	50	60	70	80	90	100
g. It was not fun or enjoyable	0	10	20	30	40	50	60	70	80	90	100
h. It became difficult to get to the physical activity location	0	10	20	30	40	50	60	70	80	90	100
i. I didn't like the particular activity or programme that I was involved in	0	10	20	30	40	50	60	70	80	90	100
j. My schedule conflicted with my physical activity	0	10	20	30	40	50	60	70	80	90	100
k. I felt self-conscious about my appearance when I did physical activity	0	10	20	30	40	50	60	70	80	90	100
l. An instructor does not offer me any encouragement	0	10	20	30	40	50	60	70	80	90	100
m. I was under personal stress of some kind	0	10	20	30	40	50	60	70	80	90	100

The following items reflect situations that are listed as common reasons for preventing individuals from eating healthily.

20. Please indicate **how confident you would feel about eating healthy foods** under each of the following circumstances.

	Not at all confident		**Neither**		**Very confident**
a. When you are bored	1	2	3	4	5
b. When you are frustrated	1	2	3	4	5
c. When you are stressed	1	2	3	4	5
d. When you are lonely	1	2	3	4	5
e. When you are angry	1	2	3	4	5
f. When you are depressed	1	2	3	4	5
g. When you are anxious	1	2	3	4	5
h. When you are happy	1	2	3	4	5
i. When you are feeling good	1	2	3	4	5
j. While eating out at a restaurant with close friends	1	2	3	4	5
k. When only unhealthy foods are readily available	1	2	3	4	5
l. When you have to prepare healthy meals for yourself	1	2	3	4	5
m. When eating a healthy meal seems just too much trouble	1	2	3	4	5
n. When eating a healthy meal means you have to cook it	1	2	3	4	5
o. When substituting a healthy for unhealthy food is a pain	1	2	3	4	5
p. When eating an unhealthy food is more convenient	1	2	3	4	5

21. When you are ***grocery shopping*****, how confident are you in your ability to:**

a. Select whole grain bread or cereal in a grocery store	1	2	3	4	5
b. Select low fat dairy products (e.g. yogurt)	1	2	3	4	5
c. Select foods that are low in sodium (salt)	1	2	3	4	5
e. Select foods that are low in saturated fat	1	2	3	4	5
f. Select foods that are low in cholesterol	1	2	3	4	5
g. Select foods that are high in dietary fibre	1	2	3	4	5
h. Select foods that are low in or free of trans fats	1	2	3	4	5

For each question, please circle the option that you feel applies best to you.

22. In the last month, I have made a detailed plan for getting a healthy amount of physical activity, including ...	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Not applicable**
a. When to exercise	1	2	3	4	5
b. Where to exercise	1	2	3	4	5
c. How to exercise	1	2	3	4	5
d. How often to exercise	1	2	3	4	5
e. What to do if something interferes with my plans	1	2	3	4	5
f. How to cope with possible setbacks	1	2	3	4	5
g. When I have to pay extra attention to prevent lapses	1	2	3	4	5

23. In the last month, I have made a detailed plan for eating a healthy diet, including ...	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Not Applicable**
a. What to eat	1	2	3	4	5
b. What unhealthy foods I want to restrict in terms of how much I eat of them	1	2	3	4	5
c. What healthy foods I want to include plenty of in my diet	1	2	3	4	5
d. What to do if something interferes with my plans	1	2	3	4	5
e. How to cope with possible setbacks	1	2	3	4	5
f. When I have to pay extra attention to prevent lapses	1	2	3	4	5

24. During the last month, I have ...	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
a. Consistently monitored whether I get enough exercise	1	2	3	4
b. Done my best to achieve my target level of physical activity	1	2	3	4
c. Not thought much about how much physical activity I get	1	2	3	4
d. Kept track of things that help me or stop me from getting enough exercise	1	2	3	4
e. Often thought about how I can overcome any problems that might stop me from getting enough exercise	1	2	3	4

25. During the last month, I have ...	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
a. Consistently monitored what I eat and how healthy it is.	1	2	3	4
b. Done my best to eat healthily	1	2	3	4
c. Not thought much about what I eat	1	2	3	4
d. Kept track of things that help me or stop me from eating a healthy diet	1	2	3	4
e. Often thought about how I can overcome any problems that might stop me from eating a healthy diet	1	2	3	4

26. How often in the last month did your family or friends ...	**Almost Never**	**Once in a While**	**Sometimes**	**Often**	**Very Often**
a. Discuss physical activity with you	1	2	3	4	5
b. Remind you to do physical activity	1	2	3	4	5
c. Encourage you to stick with your physical activity plan	1	2	3	4	5
d. Share your ideas on how to get enough physical activity	1	2	3	4	5
e. Do physical activity with you	1	2	3	4	5

27. How often in the last month did your family or friends do the following? ...	**Almost Never**	**Once in a While**	**Sometimes**	**Often**	**Very Often**
a. Encourage you to eat healthy foods.	1	2	3	4	5
b. Discuss the benefits of eating healthy foods.	1	2	3	4	5
c. Remind you to choose healthy foods.	1	2	3	4	5
d. Share ideas on healthy eating.	1	2	3	4	5
e. Eat healthy meals with you.	1	2	3	4	5
f. Complain about eating healthy foods.	1	2	3	4	5

28. Please indicate the extent to which each statement is true for you, assuming that you were intending either to begin exercising regularly or to maintain your **regular exercise** regimen.

	not at all true			somewhat true			very true
a. I feel confident in my ability to exercise regularly.	1	2	3	4	5	6	7
b. I now feel capable of exercising regularly.	1	2	3	4	5	6	7
c. I am able to exercise regularly over the long term.	1	2	3	4	5	6	7
d. I am able to meet the challenge of exercising regularly.	1	2	3	4	5	6	7

29. Please indicate the extent to which each statement is true for you, assuming that you were intending either to improve your diet now or to maintain a **healthy diet**.

	not at all true			somewhat true			very true
a. I feel confident in my ability to maintain a healthy diet.	1	2	3	4	5	6	7
b. I now feel capable of maintaining a healthy diet.	1	2	3	4	5	6	7
c. I am able to maintain a healthy diet over the long term.	1	2	3	4	5	6	7
d. I am able to meet the challenge of maintaining a healthy diet.	1	2	3	4	5	6	7

For each question, please circle the option that you feel applies best to you.

30. Getting regular physical activity is something…	Completely disagree						Completely agree
a. I do automatically	1	2	3	4	5	6	7
b. I do without having to consciously remember	1	2	3	4	5	6	7
c. I do without thinking	1	2	3	4	5	6	7
d. I start doing before I realize I'm doing it.	1	2	3	4	5	6	7

31. Maintaining a healthy diet is something…	Completely disagree						Completely agree
a. I do automatically	1	2	3	4	5	6	7
b. I do without having to consciously remember	1	2	3	4	5	6	7
c. I do without thinking	1	2	3	4	5	6	7
d. I start doing before I realize I'm doing it.	1	2	3	4	5	6	7

	Completely disagree						Completely agree
32. I feel I have choices and options about physical activity and health	1	2	3	4	5	6	7
33. I feel I have choices and options about consuming a healthy diet	1	2	3	4	5	6	7

End of questions

Thank you!

Appendix 5.5 Study 3 Post-intervention interview schedule

Thank you for agreeing to take part in an interview. Before we start I just want to reassure you that you do not have to answer a question if you don't feel comfortable to and if you would like to take a break or stop the interview at any time that is absolutely fine, just let me know. [Final verbal check that they understand and are happy to proceed]

1. The website

We would like to find out about your experience of the health programme. First of all, what were your impressions of the website?

- Attractiveness/style
- Ease of use/navigation
- Interesting (evolution aspect, physiology)

Was the information provided useful to you?

- Why?
- Which parts were more/less useful?

Was the goal recording area useful?

- Why?

What do you think would improve the website?

2. Making changes

Now thinking about the whole programme, did you make any changes to your behaviour as a result of the programme?

- What changes? [If yes to changes]

Did you find the pedometer/record book helpful?

- Why/why not?
- Were they enjoyable to use?

Was there anything in particular in the intervention that made you first make changes?

- What?
- Could this be improved?

Was there anything in particular in the intervention that helped you maintain changes?

- What?
- Could this be improved?

[If no to changes]

Why did you not make changes?

- What might have helped?

Finally, is there anything else you would like to say about your experience with the programme or study in general?

Thank you